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The interaction between K-rich melts and mantle minerals in Fernando de Noronha (Brazil) mantle xenoliths: a 3D X-ray computed microtomography and geochemical study

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To my brother
Sasha
I wish you to live
with light-heartedness, curiosity and irony

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Abstract

Fernando de Noronha (FN) archipelago is located in the Atlantic Ocean, 350 km away from NE Brazil. The products of its magmatism are three main formations: Remédios, with a potassic and a sodic series, which shows an age between 12.5 ± 0.1 and 9.4 ± 0.2 Ma, the Sao José formation (9.5 ± 0.4 and 9.0 ± 0.1 Ma) which is the only one hosting mantle xenoliths, and finally, the Quixaba formation, characterized by nephelinites erupted between 6.2 ± 0.1 and 1.3 ± 0.1 Ma (Perlingeiro et al., 2013).

Many authors focused on mantle xenoliths from this locality, tentatively searching for possible effects of the FN mantle plume on the lithosphere. Rivalenti et al. (2000) reported that FN xenoliths show evidence of modal variation induced by reaction with percolating melts. The isotopic analyses performed on their clinopyroxenes were compatible with an EMII source of metasomatism, this kind of signature is the same as the one of Remédios formation. Kogarko et al. (2001) described the presence of carbonate metasomatism. Their model comprises various degrees of partial melting, followed by the invasion of carbonate melts/fluids in the depleted material, which contaminated the mantle. The last model was proposed by Liu et al. (2019a), which theorized a continuous infiltration of asthenospheric small volume melts inside the above lithosphere, that decreased with thickening of the lithosphere and the increasing distance from Mid-Atlantic Ridge (MAR), followed by multiple episodes of reactive large volume melts percolation of the main magmas that formed the islands in the Cenozoic.

In this work, we present the direct evidence of mantle metasomatism that occurred in the archipelago. We performed both textural (optical microscopy and 3D computed microtomography) and chemical analysis (EMPA and LA-ICP-MS) on mineral phases and K-rich glasses inside xenoliths to understand the nature, dynamics, and composition of FN mantle section and to give new insight into the formation and evolution of potassic rich melts. We selected 5 samples particularly rich in glassy patches, that are characterized by the presence of several euhedral crystals, which are mainly olivine, clinopyroxene, spinel and plagioclase, with the sporadic occurrence of apatite and amphibole.

Throughout 3D X-ray computed microtomography (μ -CT), I studied in three dimensions the texture of the samples, defining quantitatively parameters that have petrological implications. The interconnectivity of the observed glasses, for example, has been discovered to be significantly high in all our xenoliths, testifying extensive percolation of the metasomatizing melts. We based the 3D textural study on a multiscale approach structured in steps of incremental resolution: conventional X-ray μ -CT with 23.33 μm of voxel size, conventional μ -CT with a voxel size ranging from 10.9 to 6.7 μm depending on the sample, and synchrotron radiation X-ray μ -CT reaching voxel sizes of 2.5 and 0.9 μm . As the attached manuscript (AppendixA, Venier et al., submitted to Lithos) testifies, this reveals to be the best way to analyze a significant volume of the sample without losing the small-scale details (visible at a resolution below the μm).

Major, minor and trace elements analyses allow us to characterize the mineral chemistry of phases and the chemistry of glasses. The latter appear as potassic in composition and are completely different from their hosting basanite, proving they are not the effect of magma infiltration during the ascent. Trace elements are far more sensible to petrological processes, rare earth elements (REE) and incompatible elements (IE) patterns allow us to understand how glasses induced metasomatism in the mantle phases and partial assimilation of orthopyroxene when alkalinity reached a sufficient level. Moreover, trace elements allow disproving some theories, such as the carbonate metasomatism evoked by Kogarko et al. (2001) and strengthened what was stated by Rivalenti et al. (2000). As a matter of fact, our samples confirmed what the isotopic composition of mantle xenolith's Cpx previously suggested: the potassic source that contaminated the mantle beneath FN is the same that originated the potassic series of Remédios formation and is due to contamination of the oceanic lithosphere as a consequence of lithospheric stretching during the opening of the Atlantic ocean.

Combining optical microscopy, 3D multiscale textural analysis and chemical analysis of both major, minor and trace elements we were able to find an exhaustive model for the mantle section beneath the Fernando de Noronha archipelago, giving direct evidence of texture and chemical composition of the metasomatizing melt that percolated our xenoliths.

1. Aim of the project

The interaction between metasomatizing melts and the phases constituting the mantle, other than the genesis of any metasomatic source, is a much-debated topic in petrology (see for example O'Reilly & Griffin, 2013; Kiseeva et al., 2017 and reference therein). In the mantle xenoliths of Fernando de Noronha, several authors reported evidence that suggested the presence of a metasomatic source underneath the archipelago (Rivalenti et al., 2000; Kogarko et al., 2001; Liu et al., 2019a, 2019b).

The main aim of this work was to investigate a suite of xenoliths coming from this locality, to improve our understanding of the processes occurring in the lithosphere underneath FN.

The approach was based on the combination of a 2D and 3D textural study with the chemical characterization of both mineral phases and possible metasomatizing glasses found inside the xenoliths. We collected textural data through conventional polarized optical microscope petrographic observations of thin sections and 3D X-ray computed microtomography to obtain the full three-dimensional model of the samples here studied. Chemical analyses were made on mineral phases and glasses with Electron Microprobe Analyses (EMPA) to obtain major and minor elements concentration and with Laser-Ablation Ion-Coupled Plasma Mass-Spectrometry (LAICPMS) to collect the trace elements content.

3D X-ray computed microtomography (μ -CT) has already shown to be much of use in geosciences (Baker et al., 2012; Arzilli et al., 2017; Bhanot et al., 2017, 2020; Patkó et al., 2020), however, it has been applied to mantle xenoliths only in recent years. Hence, we developed and verified a multiscale approach with increasing steps of resolution, using the combination of conventional 3D μ -CT and synchrotron radiation-based μ -CT. The attached manuscript (AppendixA; Venier et al., submitted to Geoscience Frontiers), shows the result of this study on 3D textures of mantle xenoliths made in collaboration with the Abdus Salam Center for Theoretical Physics (ICTP) and the SYRMEP beamline at Elettra Synchrotron facility.

Moreover, as the discussion on the existence of the FN plume is still open (see for example Klocking et al., 2020 and Guimaraes et al., 2020), we used our data, both textural and chemical analyses, to propose a new model on the mantle section beneath the archipelago.

2. Introduction

2.1 Location and geology of Fernando de Noronha

The Fernando de Noronha archipelago is located in the Equatorial Atlantic Ocean off the coasts of South America approximately 350 kilometers away from north-eastern Brazil and belongs to the Brazilian state of Rio Grande do Norte. The archipelago (Fig.1) occupies an area of 18.4 km² in a 100-105 Ma old oceanic crust (based on magnetic anomaly data from Nemcok et al., 2013) and it is composed of 19 islands, the larger of which measures 16.9 km². The main volcanic edifice has a diameter of 60 m and a depth of 4000 m under the ocean surface, it is associated with the E-W volcanic alignment of the Mecejana volcanic field (Perlingeiro et al., 2013). According to Liu et al. (2019), this alignment may have superimposed a Mesozoic oceanic transcurrent fault (Chain fracture zone). This appears in agreement with the general behaviour of oceanic tectonics in that region. Other authors stated that the archipelago belongs to a larger volcanic complex positioned along the Fernando de Noronha ridge, and stretching E-W for 75 km following the trending fracture zone (Almeida, 1955, 2012). In both theories, fracture zones may have channelled to the surface mantle-derived magmas. If the magmatism is not tectonic driven, the only other possibility is that the volcanic alignment is following a hot-spot track, but this appears in contrast with the plate movement which, in the last 80 Ma, according to the south American paleomagnetic data from Ernesto et al. (2002), has a SE-NW direction. Following Mizusaki et al. (2002), Almeida (2012), Perlingeiro et al. (2013), and reference therein, the volcanic alignment is associated with a hot spot (Fernando de Noronha mantle plume; Perlingeiro et al., 2013; Lopes & Ulbrich, 2015) moving W-E. Notably, this movement is extrapolated from Gripp & Gordon (2002) that studied a planetary-based dataset on paleomagnetic reconstructions.

The older magmatism along the Mecejana volcanic field is found on the continental margin. New ⁴⁰Ar/³⁹Ar dating performed by Guimaraes et al. (2020) attests to ages between 35.03 ± 0.28 and 30.08 ± 0.22.

Concerning the oceanic structures of the investigated magmatism, they are forming the small archipelago called Fernando de Noronha and several seamounts whose ages are actually unknown. Considering Fernando de Noronha, it is characterized by several eruptions of different ages, ⁴⁰Ar-³⁹Ar data from Perlingeiro et al. (2013) span from 12.5 ± 0.1 to 1.3 ± 0.1 Ma, which do not show a sequence along the hot-spot track. According to Klocking et al. (2020) and Guimaraes et al. (2020), this is in contrast with the normal evolution of a plume track. Moreover, basic and acidic magmas

are randomly distributed along the entire temporal sequence, suggesting a continued replacement of the magmatic chambers during a period of almost 10 Ma.

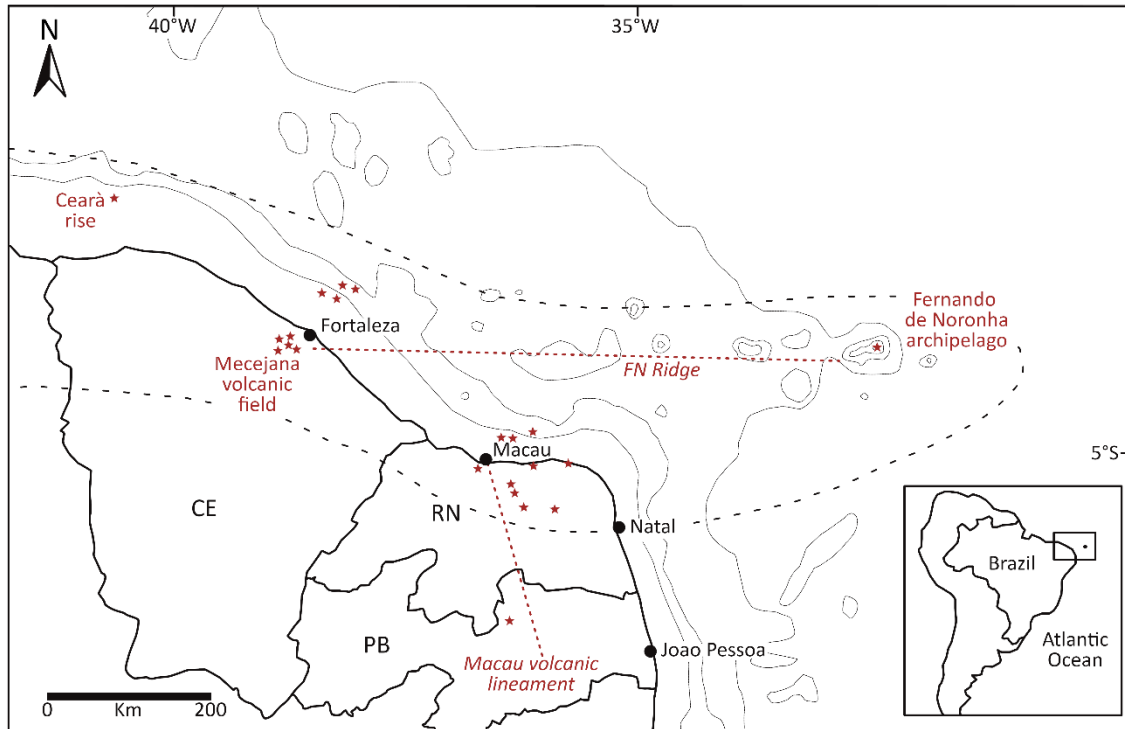


Figure 1: location map for the area object of study, modified from Perlingeiro et al. (2013). Red stars indicate the main igneous occurrences, black dotted line as hypothesised FN plume track.

2.2 Main features of Fernando de Noronha lithotypes

Considering several parameters (chemistry, petrography, dating) several authors (Almeida, 1955; Fodor et al., 1998; Ulbrich & Lopes, 2000; Lopes, 2002; Lopes & Ulbrich 2015) grouped the volcanics from Fernando De Noronha in three main formations: Remédios formation, forming the bulk core of the island, is the older one with ages between 12.5 ± 0.1 and 9.4 ± 0.2 Ma. It is followed by the Sao José formation, with ages ranging from 9.5 ± 0.4 and 9.0 ± 0.1 Ma, which is the only one hosting the mantle xenoliths object of this thesis. Finally, the younger one, which is the Quixaba formation, erupted between 6.2 ± 0.1 and 1.3 ± 0.1 Ma.

Remédios formation (Almeida, 1955; Fodor et al., 1998; Ulbrich & Lopes, 2000; Lopes, 2002) is characterized by two alkaline (K and Na) series showing different lithological types (Fig.2). According to Lopes & Ulbrich (2015), the potassic suite is characterized by: alkali basalts, basaltic trachyandesites, trachyandesites and trachytes. Moreover, several ultrapotassic, potassic and probably partially spilitized (see the Na lamprophyre of Lopes & Ulbrich, 2015) lamprophyres are

reported inside the Remédios formation. The sodic magmas are not well characterized, as they zigzag in the K-Na diagram (Middlemost, 1975) along the potassic-sodic boundary. In the author's opinion, an accurate study of the sea water-related alteration on these samples, which has not been already done, is needed. In any case, the Na magmas are represented by pyroclastites, flows, dikes and sills that all together, according to Lopes & Ulbrich (2015), identify an alkaline Na suite: the lithotypes span from basanites, amphibole-rich tephrites, essexite (sill) and porphyry and aphyric phonolites. As visible in Fig.2, among all the lithotypes, pyroclastic material and phonolites cover almost all the outcrops of their formation, while other lithologies mainly appear as dikes and sills. All the flows and dykes are variably porphyritic and seriate with the exception of a few phonolites. The main phases are olivine in the less evolved samples and clinopyroxene which is present like diopside evolving toward aegirine augites following the fractionation. Plagioclase is rare while alkali feldspar, Na amphibole and a few sodalites are present in the more evolved samples. Magnetite is variably present in all rock types. The essexite is characterized by a ipidiomorphic texture and shows olivine, clinopyroxene, magnetite, rare plagioclase and idiomorphic nepheline in the groundmass. Apatite represents the most common accessory phase.

Sao José formation is characterized by basanite plug hosting mantle xenoliths. The ages are coupled with the younger ones of the Remédios formation. They are mainly characterized by olivine and titan augite phenocrysts while the groundmass show presence of glass, nepheline in grain and other mafic minerals not well defined in the literature, which could be xenocrysts. Secondary analcime is Highlighted by Lopes & Ulbrich (2015). Notably, the presence of this mineral could be related to glass recrystallization, but could also suggest the presence of primary Leucite. No studies have yet been carried on about this, to our knowledge. Despite being correlated to the Remédios formation by their ages, these basanites represent for all the authors (Almeida, 1955; Fodor et al., 1998; Ulbrich & Lopes, 2000; Lopes, 2002; Lopes & Ulbrich 2015) a separate minor event, with a direct eruption mechanism that connected the original melting source with the surface, as testified by the abundance of xenoliths. This magmatic small complex (Sao José Island, highlighted in blue in Fig.2) is identified as an independent formation for these features.

The younger formation of Quixaba is petrographically uniform and constituted mainly by strong alkaline and basic flows which span from melilites to melano-nephelinites and basanites (Lopes & Ulbrich, 2015; Fig.2). This event is considered to have experienced less differentiation with respect to the Remédios formation, deriving directly or nearly directly from primitive magmas. The

main mineral phases are well-formed olivine, diopside and magnetite. Plagioclase is absent while nepheline and analcime are common in the groundmass.

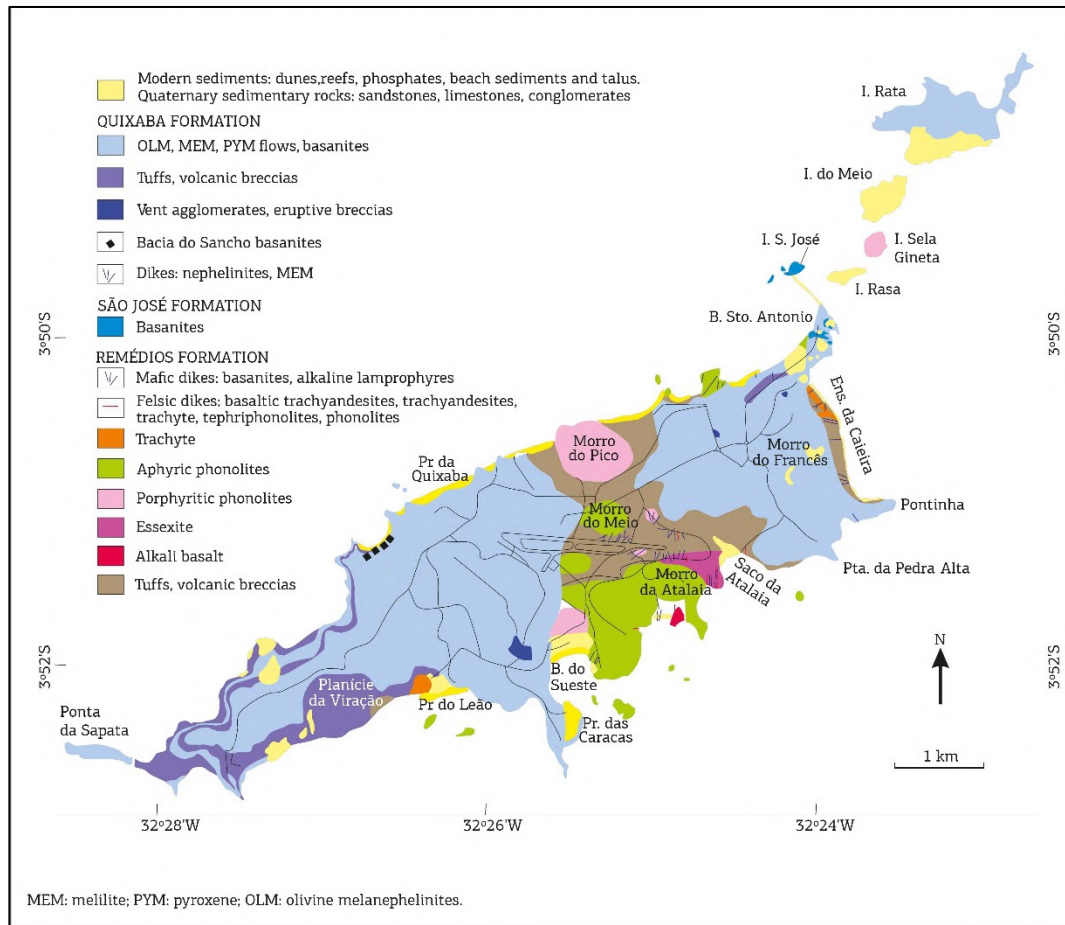


Figure 2: Geological map of Fernando de Noronha, modified from Lopes & Ulbrich, 2015.

In summary, the archipelago is the result of different magmatic pulses, which, according to Mizusaki et al. (2002), Almeida (2012), Perlingeiro et al. (2013) and Lopes & Ulbrich (2015) is triggered by intermitting melting of an enriched sub-oceanic mantle source due to heat transfer by an active deep plume. This process is supposed to be generated by the FN plume, beginning inland in the Pernambuco state, and moving into the oceanic domain as a consequence of plate drifting (Fodor et al., 2002; Lopes & Ulbrich, 2015). Moreover, in northeastern Brazil, Ocean Island Basalt (OIB)-like alkali basalts occurring as necks and plugs in Rio Grande do Norte are believed to represent the surface track of the Fernando de Noronha hotspot, that was underneath that area 30 Ma ago (Fodor et al., 1998; Rivalenti et al., 2000). Fodor et al. (1998) concluded that these inland basalts derived from the mixing of an asthenospheric melt, characterized by High- μ (HIMU) and Depleted Mantle (DM) isotopic signatures, with a Sub Continental Lithospheric Mantle (SCLM) melt close to the

Enriched Mantle I (EMI) isotopic signature. They differ isotopically from the Fernando de Noronha formations, which are enriched in Zr and Nb, depleted in Th and display slightly higher $^{143}\text{Nd}/^{144}\text{Nd}$ (Fodor et al., 1998). Gerlach et al. (1987) identified three different isotopic components in the FN lavas: HIMU, DM and EMII. Alkalic basalts from north-western Brazil and those of Fernando de Noronha, therefore, shared similar sources, characterized by HIMU and DM isotopic signatures, but not identical source materials, as they are trending to EMI and EMII respectively.

Some authors (Fodor et al., 1998; Rivalenti et al., 2000) speculated that EMII component derives from a lithospheric reservoir that may have underlain Fernando de Noronha even though this is an oceanic province. However, the presence of distinct metasomatic components in two localities genetically related to the same plume is difficult to be explained, particularly since evidence of metasomatism in both localities is, up to now, based on indirect clues. Other works advanced doubt on the existence of the FN mantle plume (Guimaraes et al., 2020; Klocking et al., 2020) proposing a new hypothesis that combines the Atlantic ocean opening to a mechanism of regional uplift due to emplacement of a warm lithosphere beneath a plate that experienced thermomechanical erosion and lithospheric thinning. Klocking et al. (2020) in particular highlighted how there is no evidence, neither chemical nor seismic, supporting the existence of large scale thermal anomalies beneath the FN archipelago. Anyway, both Guimaraes et al. (2020) and Klocking et al. (2020) reported discrepancies in the results of geochemical calculations for Fernando de Noronha data, addressing the reason to the presence of some kind of metasomatism occurred in the mantle beneath the islands.

2.2 Mantle xenoliths from Fernando de Noronha: state of the art

Many authors focused on mantle xenoliths from this locality, tentatively searching for possible effects of the FN mantle plume on the lithosphere (Rivalenti et al., 2000; Kogarko et al., 2001; Liu et al., 2019). All xenoliths are spinel peridotites, mostly lherzolites with olivine ranging from 50% to 75% and clinopyroxene from about 5% to 15% in modal abundances, harzburgites are present but quite rare. According to several authors (i.e. Rivalenti et al., 2000; Kogarko et al., 2001; Liu et al., 2019) a group of xenoliths, the less represented population, may be considered porphyroclastic. The others have been named protogranular, coarse-grained and coarse-porphyroclastic, however, considering the abundance of polygonal phases and straight boundaries, forming triple junctions, we speculate that the definition given in previous works is incorrect. According to Mercier and

Nicolas (1975), as this type of xenoliths strongly experienced subsolidus recrystallization, we suggest that granuloblastic may be a more appropriate texture.

Rivalenti et al. (2000) reported that FN xenoliths, in particular the ones presenting a porphyroclastic texture, show evidence of modal variation induced by reaction with percolating melts. These evidences are the dissolution of orthopyroxene and the crystallization of clinopyroxene, highlighted by the high Cpx/Opx ratio at a constant Cpx modal content for the FN xenoliths with respect to other occurrences. In this study, re-analysing the same suite of xenoliths, melt inclusions have been found as glassy patches with evidence of magmatic crystallization inside. Their paragenesis include olivine, clinopyroxene, plagioclase, magnetite and apatite. Undoubted a reaction of the orthopyroxene, as suggested by Rivalenti et al (2000), is observable but this do not completely justify the chemistry of these melts which are all potassic except for one occurrence.

According to Rivalenti et al. (2000) all the xenoliths testify an average temperature of 1035 ± 80 °C. If we consider this temperature as representative of the geotherm, we must suppose that these xenoliths have been reequilibrated at a depth of 65-80 km, which is consistent with a spinel facies. As suggested by Rivalenti et al. (2000) that, using Ca-in-olivine geobarometer of Kohler and Brey (1990), indicate a pressure in the range 1.0-2.3 GPa. Notably the higher pressures well justify the spinel facies while the lower ones are consistent with the presence of plagioclase inside the glassy potassic patches we found in our samples.

Chemical analysis on Cpx from FN samples evidenced LREE enrichment and HFSE negative anomalies, that are thought to be related to LILE-enriched melts. Anyway, this metasomatic agent was only supposed, as Rivalenti et al. (2000) did not find any direct evidence of interaction between mantle xenoliths and infiltrated melts. The isotopic analysis performed on their Cpx were compatible with an EMII type source of metasomatism, different from the one inferred for xenoliths coming from inland magmatism (EMI type metasomatism; Rivalenti et al., 2000). This kind of signature is compatible with the one of Remédios formation as testified even by Gerlach et al. (1987), which are compatible even considering the La_N/Yb_N ratios. For these reasons, the authors speculated that the Remédios event may be the metasomatic agent or the melt resulting from the metasomatic process underneath the Fernando de Noronha archipelago (Rivalenti et al., 2000).

Kogarko et al. (2001) hypothesized a more complicated history for the Fernando de Noronha mantle xenoliths, invoking the presence of carbonate metasomatism. As a matter of fact, their model comprises various degrees of partial melting with loss of incompatible trace elements and even some major components such as Ca, Al, Ti and Na. The depleted material was invaded by carbonate

melts/fluids, which contaminated the mantle with sodium and even potassium, sulfur, light rare earth elements, titanium, strontium, barium, and phosphorous. Finally, Kogarko et al. (2001), imagined a rapid ascent, as they say otherwise carbonate melt would not survive. They speculated the last equilibration between mineral phases at 3-5 km depth, while the first stages of metasomatism occurred during the uplift of mantle material from depths of 1-2 GPa (Kogarko et al., 2001), consistent with the data of Rivalenti et al. (2000).

The last model treating FN mantle comes from Liu et al. (2019), synthesized in Fig.3. Authors found out FN xenoliths have more fertile chemical composition than the ones coming from the mid-Atlantic ridge (MAR), which show a DMM-like composition. The reason why lies in the lower degree of partial melting experienced by the cooler and accreted lithosphere far from the ridge, but even in a two-stages melt-rock metasomatic interaction. Liu et al. (2019), theorized a first infiltration of asthenospheric melts inside the lithosphere, probably decreasing with increasing distance from the MAR. The second process is associated with the main magmatism that occurred in the archipelago, and its reactive percolation inside the lithosphere.

In summary, what all the authors agree with is the presence of some kind of metasomatism underneath the archipelago. The only study in which this metasomatism was directly observed and analyzed since now, to our knowledge, is the one by Kogarko et al. (2001) that identified the metasomatism as carbonatitic, in contrast with the other theories.

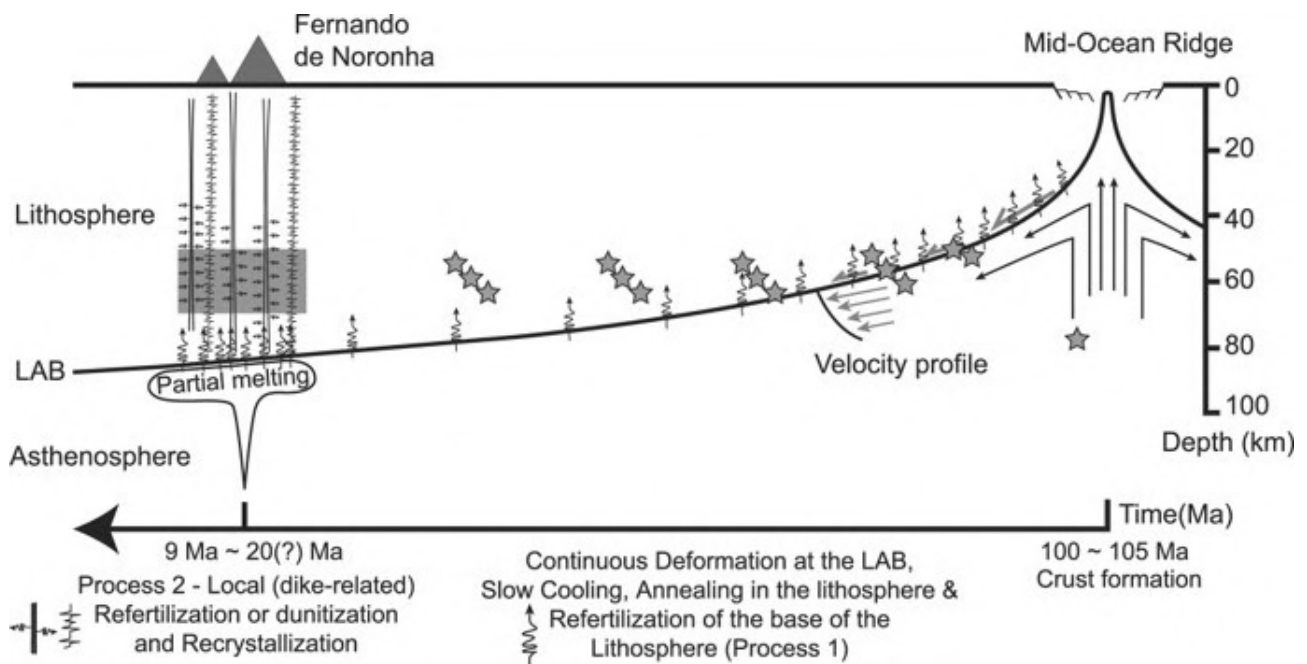


Figure 3: Schematic diagram by Liu et al. (2019), showing their proposed evolution for the oceanic mantle section. The horizontal axis represents time (not to scale). Grey stars and rectangles represent predicted positions of the xenoliths at different times. The lithosphere-asthenosphere boundary (LAB) evolution corresponds to the CHABLIS model prediction.

3 Materials and Methods

3.1 Sample selection

In this thesis, the object of study are the ultramafic mantle xenoliths coming from the basanites of Sao José formation (Fernando de Noronha archipelago). Xenoliths show different grain sizes and are widespread inside these flows. The investigated ones are in the range of 0.5 to 20 cm in size, from subrounded to angular (Fig.4) and without naked-eye evidence of alteration.

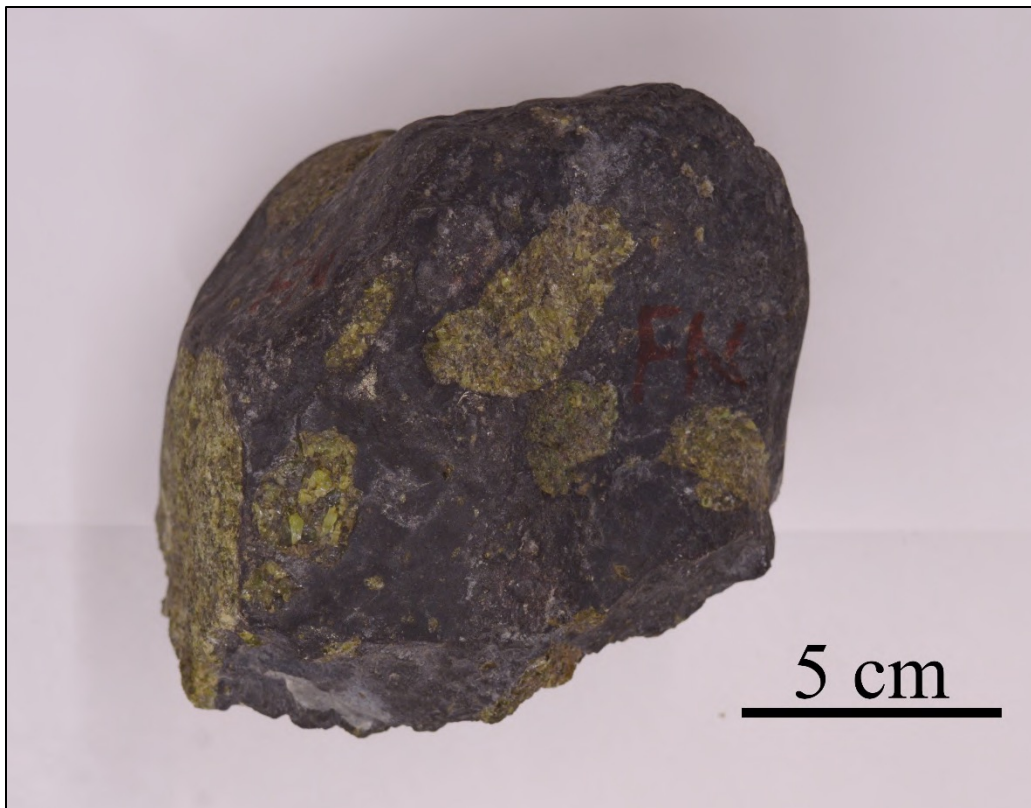


Figure 4: large sample of Sao José basanite hosting several mantle xenoliths, notice the various dimensions of xenoliths and their different shapes.

The main constituent phases are olivine (Ol), Cr-diopside (Cpx), orthopyroxene (Opx) and spinel (Sp) and have been classified as spinel lherzolites (46 samples) and harzburgites (2 samples). After a careful evaluation of 48 thin sections, five were selected among others because of the abundance of glassy patches inside and the absence of serpentinization or other alteration. We focused on five (FN14, FN18, FN30, FN38, FN41) samples, splitting the work between textural

and geochemical characterization. For the study's textural part, we used thin sections, observed in optical microscopy, entire rock samples analysed through conventional X-ray computed microtomography (μ -CT) and subsamples analysed with synchrotron radiation-based X-ray computed microtomography. For what concerns the mineral chemistry, we performed Electron Microprobe Analysis (EMPA) and Laser Ablation-Ion Coupled Plasma-Mass Spectrometry (LA-ICP-MS) on selected phases and glasses inside thin sections.

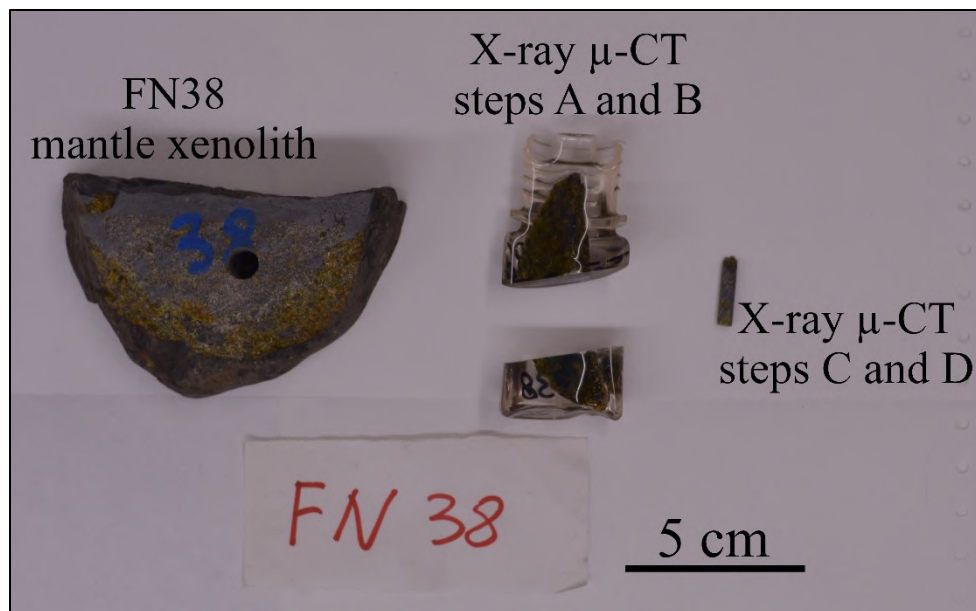


Figure 5: one of the five mantle xenoliths object of this study. Large sample from which thin sections were made and smaller cuttings, under epoxy resin, used for computed microtomography analysis.

3.2 Optical microscopy

Every sample was cut in order to obtain thin sections of about 30 microns with polished surfaces. Thin-section preparation was performed at the University of Padova, Department of Geosciences, 2D textural analysis of samples was carried out in the University of Trieste, Department of Mathematics and Geosciences with Leitz Wetzlar optical microscope equipped with 5 lenses of respectively 2.5/ $0.08\times$, 6.3/ $0.20\times$, 16/ $0.43\times$, 25/ $0.55\times$, 40/ $0.70\times$ and a Canon EOS 700D camera. All the images of thin sections were taken using the Canon camera and modified with the open-source software Gimp (Gnu Image Manipulation Program).

3.3 X-ray Computed Microtomography

First of all, as μ -CT applied to textural studies of mantle xenolith is a relatively new technique (Troll et al., 2012; Bhanot et al., 2017; Patkó et al., 2020), we decided to test the effectiveness of a multiscale approach. As using only samples coming from the same source can lead to misinterpretation of the resulting data, or may be almost simplistic, we made the test with three different samples coming from different geodynamic settings, thus showing possibly different textures: mantle xenolith MG10x comes from a volcanic edifice (45°38'55.56N; 106°22'19.38E) south of Mandalgovi, Sajncagaan District, Central Mongolian plateau; sample Bi4 comes from the Bou-Ibalrhatene maar (33°20'11.52''N - 5°3'24.16''W), middle Atlas basaltic province, Morocco; finally, FN38 xenolith sample coming from the basanite of Sao José formation which is one of the five mantle xenoliths extensively studied on this thesis. Results are summarized in a methodological paper, which is under review, that is integrally attached in AppendixA.

The characterization through μ -CT included three to four steps with increasing spatial and contrast resolution for each sample.

Step A involved cone-beam polychromatic μ -CT imaging at the Multidisciplinary Laboratory (MLab) of the "Abdus Salam" International Centre for Theoretical Physics (ICTP, Trieste, Italy) (Tuniz et al., 2013). In this step, we analysed only one sample, in order to obtain a first complete 3D reconstruction of the xenoliths microstructure. The tomographic scanning was carried out by using a sealed microfocus X-ray source (Hamamatsu L8121-03) at a voltage of 110 kV, a current of 90 μ A and a focal spot size of 7 μ m. The X-ray beam was filtered by a 0.1 mm-thick copper filter. A set of 1440 radiographs (projections) of the xenoliths was recorded over a total scan angle of 360° by a 12-bit, 2400x2400 pixels flat panel detector (Hamamatsu C7942SK-25, pixel size: 50 μ m). The virtual axial slices were reconstructed using the commercial software DigiXCT (DIGISENS, France) in a 32-bit format with an isotropic voxel size of 23.33 μ m.

Step B involved cone-beam polychromatic X-ray imaging measurements performed at the TomoLab station, a laboratory μ -CT instrument available at the Elettra synchrotron facility in Trieste (Italy). The instrument is equipped with a sealed microfocus X-ray source (Hamamatsu L9181) with a minimum focal spot size of 5 μ m (Mancini et al., 2007; Zandomenighi et al., 2010).

The TomoLab instrument can operate both in absorption and phase-contrast modes (Wilkins et al., 1996; Polacci et al., 2009). A set of 2400 projections was acquired for every sample, over a total scan angle of 360°. The detector was a water-cooled CCD camera (Photonic Science XDI-VHR, UK) with a 12-bit dynamic range and 4008 x 2672 pixels, with a gadolinium oxysulfide scintillator screen coupled to a fibre-optic taper. A 2 x 2 binning was applied to the detector pixels in order to improve the signal-to-noise ratio. Scanning conditions were as follow: voltage = 130 kV, current = 61 μ A, filter = 1.5 mm-thick Al foil, exposure time per projection = 6.5 s, source-to-sample distance = 150 mm and source-to-detector distance = mm. The axial slices reconstruction was made by the commercial software COBRA (Exxim, USA) in 16-bit format with an isotropic voxel size ranging between 6.7 and 10.9 μ m.

In this step, we focused on some volumes of interest (VOIs) inside the xenoliths, so the 3D rendered volumes are smaller than the entire samples.

Both software tools used for tomographic reconstruction in steps A and B are based on the FDK algorithm (Feldkamp et al., 1984) for the cone-beam geometry of the X-ray beam.

Steps C and D involved the use of synchrotron radiation microtomography at the SYRMEP beamline of Elettra (Tromba et al., 2010). Cylindrical samples of 4 mm in diameter were drilled or cut out of the sub-volumes analysed in Step B. At SYRMEP, a bending magnet source delivers a nearly parallel, laminar section X-ray beam, with a maximum area of 160 x 6 mm, at a distance of ca. 24 m from the source. The beamline is equipped with a Si (111) double crystal monochromator allowing it to work at an energy between 8.3 and 40 keV. It is also possible to work in white-beam (polychromatic) mode. Our experiment was performed using a filtered white beam (filters: 1.5 mm Si plus 1.0 mm Al) with a mean energy of c. 27 keV. For each scan 1440 projections were acquired over a total scan angle of 180° during a continuous sample rotation, acquired by a water-cooled, 2048x2048 pixels, 16-bit sCMOS macroscope camera (Hamamatsu C13440-20CU) lens-coupled to a 17 μ m-thick GGG:Eu scintillator screen. The μ -CT experiments were carried out in propagation-based phase-contrast mode (Cloetens et al., 1997) setting a sample-to-detector distance of 150 mm. Steps C and D involved the acquisition of images with an effective pixel size of 2.5 and 0.9 μ m, respectively. While in step C we analysed samples in their entire diameter, in step D we imaged sub-volumes of interest, as at higher spatial resolution

smaller volumes of the entire sample will be probed by the X-ray beam (region of interest μ -CT). The tomographic reconstruction was carried out by using the Syrmep Tomo Project (STP) software suite developed at Elettra (Brun et al., 2015) based on the filtered back-projection algorithm and powered by the ASTRA Toolbox (Van Aarle et al., 2015). Before tomographic reconstruction, a single-distance phase-retrieval algorithm was applied to the projection images. The δ/β parameter (ratio between the departure from a unit of the real part and the imaginary part of the refraction index of the investigated sample material) was optimized for the different samples. This optimisation was done on an ad-hoc base in order to increase the visibility of the phases of interest.

Sample:	Pixel sizes (μm)			
	MLab	Tomolab	SYRMEP	
	Laboratory	Laboratory	Beamline	
	<i>step A</i>	<i>step B</i>	<i>step C</i>	<i>step D</i>
<i>MG10x (t.s.)</i>	30	10	2.5	-
<i>Bi4 (t.s.)</i>	21	6.25	2.5	0.9
<i>FN38 (t.s.)</i>	23.33	6.7	2.5	0.9
<i>FN14</i>	-	17.5	2.5	0.9
<i>FN18</i>	-	12.5	2.5	0.9
<i>FN30</i>	-	17.5	2.5	0.9
<i>FN41</i>	-	17.5	2.5	0.9

Table 1: Pixel sizes for different μ -CT scan carried out on the mantle xenoliths in this study. T.s. indicate samples used in the testing of X-ray computed micro-CT effectiveness (AppendixA).

3.4 3D image processing and analysis

One of the main steps in μ -CT is the definition of a representative elementary volume (REV) which averages all the variable properties of the sample. Considering the nature of any mantle xenolith,

which represents a single piece of the lithospheric mantle suspended at the time of its eruption, every sample is equally significant and, except for the peripheric layer which may be altered by the hosting basalt, all the volume needs to be taken into account. For these reasons, we believe the only way for being sure to cover a sufficient volume to be considered a REV is a multiscale approach here presented. In every 3D model, we isolated a volume of interest (VOI) as large as possible, verifying that in the subsequent step we were going to analyse a part of the sample still representative of all its properties.

For all μ -CT setups employed, the virtual sections (both raw and processed data) were visualized by using the open-source software ImageJ (Schneider et al., 2012) while the 3D visualization, through isosurface or volume rendering tools, was performed by the Dragonfly software. Image processing and analysis were performed by using the Dragonfly software, version 2020.2 for Windows, using a free-of-charge license for academic use (ORS, Canada).

The first step of the data analysis was 3D image segmentation carried out using the corresponding panel integrated into the software, comparing the grayscale with a threshold or a locally adaptive threshold in the more complex cases. Sometimes the complexity of data, or too low-density contrasts required a semi-automatic segmentation coupled with interpolation operations. After every segmentation, a cleaning procedure was performed to exclude from the region of interest (ROI) segmented all the small defects, undesired and/or unphysical objects. Segmentation and cleaning operations were based not only on morphology (erosion and dilation of the selected volume) but even on topology (connectivity, elongation, voxel count, etc..). For each ROI extracted from ours VOI, several structural, morphological and textural parameters can be computed. In particular, if the ROI is composed of disconnected volumes, as in the case of different spinel crystals, for example, the connected component analysis allows to separate, label and quantify several parameters for each element. We summarize the more useful in Table 2. Knowledge of the surface area, other than shape, volume, diameter, sphericity, and many other parameters is particularly useful when considering mineral phases as it will allow defining the origin of a crystal, but even in understanding the nature and the formation of pores and vesicles. When in the presence of an interconnected volume, on the other hand, Dragonfly software enables to perform a skeleton analysis, that allows investigating the complexity of

interconnected spaces. Throughout this analysis we determined the number of vertices and edges of the skeletal model, deriving edges/vertices ratios, Euclidean length of edges, Euler characteristic number and connectivity density of analyzed objects. Euler number and connectivity density in particular give an idea of skeleton complexity and connectivity, which are negatively correlated to these two values.

Parameter	Notes
<i>Voxel count</i>	The total number of voxels in each labelled object.
<i>Volume</i>	The volume occupied by each labelled object, that is, the amount of space inside of the object.
<i>Surface</i>	Is the surface area of each labelled object, that is, it refers to the outside area of the object.
<i>Volume/Surface</i>	Calculated volume-to-surface area ratio.
<i>Phi</i>	The angle from the X-axis of the projection on the XZ plane of the orientation.
<i>Theta</i>	The angle from the X-axis of the projection on the XY plane of the orientation.
<i>Aspect ratio</i>	The proportional relationship between the smallest eigenvalue and the largest inertia eigenvectors. A perfect cube or sphere would have an aspect ratio of 1.0, while a square or circle would have an aspect ratio of 0.5.
<i>Mean intensity</i>	Mean value of all voxels found for each object.
<i>Elongation</i>	The ratio of the minimum orthogonal Feret diameter to the maximum Feret diameter.
<i>Entropy</i>	The histogram-based descriptor in image processing entropy might be used to classify textures, a certain texture might have a certain entropy as certain patterns repeat themselves in approximately certain ways. A component with low entropy is more homogenous than a component with high entropy.

Table 2: main connected components analysis parameter used in the data processing. Complete descriptions can be found at www.theobjects.com/dragonfly

Petrographic characterization of the thin sections allowed to identify up to nine different phases: olivine, clinopyroxene, orthopyroxene, plagioclase, spinel, glass, apatite, zeolite, and fractures/voids. Segmentation of the μ -CT data was hence performed bearing in mind the

possible presence of such phases and by cross-checking the data with the results of petrography on thin sections.

3.5 Scanning Electron Microscope (SEM) and Electron Microprobe Analysis (EMPA)

Back Scattering Electron (BSE) images and chemical analyses were obtained by wavelength-dispersive spectrometry with a JEOL JXA-8200 electron microprobe at the Department of Earth Sciences “Ardito Desio”, Milano (Italy). Analyses were performed under the following working conditions: 15 kV acceleration voltage, 5 nA beam current and 1 μm beam size. Peak and background counting times were 30s and 10s (for each side of the peak), respectively. Standards used were a combination of natural and synthetic minerals as well as pure metals: grossular for Al, pure Cr for Cr, olivine for Mg, ilmenite for Ti, fayalite for Fe, niccolite for Ni and rhodonite for Zn and Mn.

3.6 Laser Ablation Ion-Coupled Plasma Mass-Spectrometry (LA-ICP-MS)

Laser Ablation-Ion Coupled Plasma-Mass Spectrometer (LA-ICP-MS) analyses were carried out using a New Wave UP213 (New Wave, UK) LA system coupled with a Thermo Electron X7 (Thermo Electron Corporation, Waltham, USA) ICP-MS at the Department of Physics and Geology in Perugia (Italy). The LA system was a frequency quintupled Nd:YAG laser, whose fundamental wavelength of 1064 nm was converted into 213 nm. Helium was used as carrier gas and mixed with argon make-up gas before entering the ICP torch, permitting the maintenance of stable and optimum excitation conditions. Laser repetition rate and laser energy density were fixed to 10 Hz and 10 J/cm² respectively. The analyses were conducted using a 25 μm beam diameter for the mineral phases, downscaling the spot size to 15 μm for the thinnest rims or in presence of fluid inclusions or spongy rims. Despite these precautions, some analyses among the ones reported in the appendix show values that may suggest contamination by inclusions or by surrounding glass. For spinel in particular several spots have ²⁹Si > 30000 ppm, thus were excluded from results. The same carefulness was adopted for some olivine spots showing ²³Na values higher than 1000 ppm. Glasses were analysed with a 30 μm beam diameter, in order to obtain a more mediated analysis for every spot. Detected isotopes were: ⁷Li, ⁸Be, ²³Na, ²⁴Mg, ²⁷Al, ²⁹Si, ³⁹K, ⁴²Ca, ⁴⁵Sc, ⁴⁷Ti, ⁵¹V, ⁵³Cr,

⁵⁵Mn, ⁵⁹Co, ⁶⁰Ni, ⁶⁵Cu, ⁶⁶Zn, ⁷¹Ga, ⁸⁵Rb, ⁸⁸Sr, ⁸⁹Y, ⁹⁰Zr, ⁹³Nb, ¹³³Cs, ¹³⁷Ba, ¹³⁹La, ¹⁴⁰Ce, ¹⁴¹Pr, ¹⁴⁶Nd, ¹⁴⁷Sm, ¹⁵³Eu, ¹⁵⁷Gd, ¹⁵⁹Tb, ¹⁶³Dy, ¹⁶⁵Ho, ¹⁶⁶Er, ¹⁶⁹Tm, ¹⁷³Yb, ¹⁷⁵Lu, ¹⁷⁸Hf, ¹⁸¹Ta, ²⁰⁸Pb, ²³²Th, ²³⁸U. The analyses were calibrated against NIST SRM 610 (Pearce et al., 1997) and USGS BCR2G (Rocholl, 1998) glass reference materials. Mg values obtained by EMPA were used as internal standards for spinel, while Si EMPA analyses were used as internal standards for the other phases. Precision (expressed as relative standard deviation) was better than 10% for all the elements, while accuracy (expressed as relative deviation from the reference value) was always better than 11% with the only exception of Pb (15% ca.).

4. Petrography

Mantle xenoliths from the Sao José basanites appear angular to subangular (Fig.4) but sporadically may be rounded in shape, they have various dimensions reaching 30 cm in diameter in larger occurrences. Macroscopic samples were all greenish to dark green in colour, without appreciable fractures and not showing any clue of alteration. Recognizable constituent phases to the naked eye were olivine, clinopyroxene, orthopyroxene and spinel. Observed in thin sections, they appear mainly as granuloblastic spinel-facies lherzolites, according to Mercier and Nicolas (1975), with straight grain boundaries and triple junctions. But there are even protogranular spinel facies xenoliths with coarse-grained texture (crystals can be large up to 3 mm) and smooth curved grain boundaries. Spinel appears as holly-leaf, dark-brown in colour, and is usually interstitial to pyroxenes. One thin section (FN16), considering the arrangement of spinel, shows evidence of tabular texture. A subgroup of mantle xenoliths shows clear evidence of bi-modal distribution in the size of all the phases and for this reason is classified as porphyroclastic, according to Mercier and Nicolas (1975). Previous studies on mantle xenoliths from this locality are in agreement with these observations (Princivalle et al., 1999; Rivalenti et al., 2000; Kogarko et al., 2001; Liu et al., 2019). Some xenoliths from both granuloblastic and protogranular groups show evidence of reactive melt percolation or directly display the presence of melt, as glassy patches, that show evidence of fractionation. This evidence may represent: the intrusion of the hosting basanites inside xenoliths, partial melting of hydrous phase during the uplift of the mantle xenoliths or, more probably, a metasomatic melt. For these reasons, we decided to focus our attention on five xenoliths with the largest glassy patches, characterized by the presence of a population of newly crystallized euhedral phases inside. The five selected samples are FN14, FN18, FN30, FN38 and FN41 (Fig.6).

Due to the feature of these xenoliths, we decided to deal with separately mantle minerals (identified with number 1) and magmatic phases (identified with number 2).

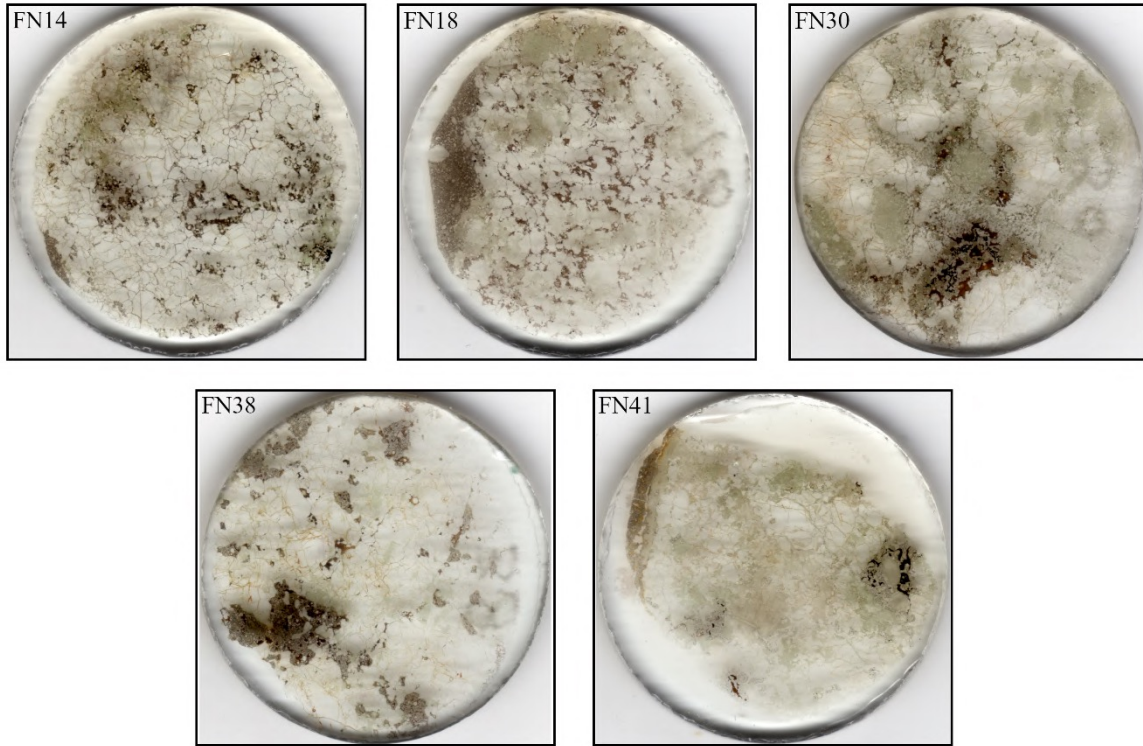


Figure 6: Thin sections, with a diameter of 2.5 cm, observed in transmitted light.

According to Mercier and Nicolas (1975), mantle phases in all five samples are consistent with those of a protogranular lherzolite, where it is possible to find evidence of subsolidus recrystallization (triple junctions among the crystals), prevalently regarding olivine grains which also show evidence of stress through the presence of kink-banding. They occasionally show fractures mainly filled by serpentine. All the silicate phases have usually fluid inclusion trails (FIT), clinopyroxene is spongy in all the samples, rarely presenting a uniform core, suggesting they experienced partial melting processes assisted by infiltration of a fluid/melt. There was no evidence of exsolution lamellae in pyroxenes.

Spinel is present among mantle phases as very dark brown with holly leaf texture only in the samples FN30 and FN41 (Fig.8C). Instead, in all the samples spinel is always present as newly formed phase inside the glassy patches.

The contact between glass and mantle phases is noteworthy, as there are many different cases. Usually, olivine and orthopyroxene develop several tiny crystals of newly formed and euhedral olivine, as visible in Figs.7 and 8C. This suggests the reaction of the orthopyroxene with an undersaturated silica melt, with consequent loss of silica by the Opx which is captured by the melt patches (Fig.8C). Clinopyroxenes act as seed crystal when in contact with glassy patches, developing in pink crystals (optically Ti-augites). In some other cases, olivines show a smooth and curved boundary between the mineral and the hosted glass, suggesting that mantle olivine may have been melted or re-equilibrated (see Ol1 crystals in Fig.8D).

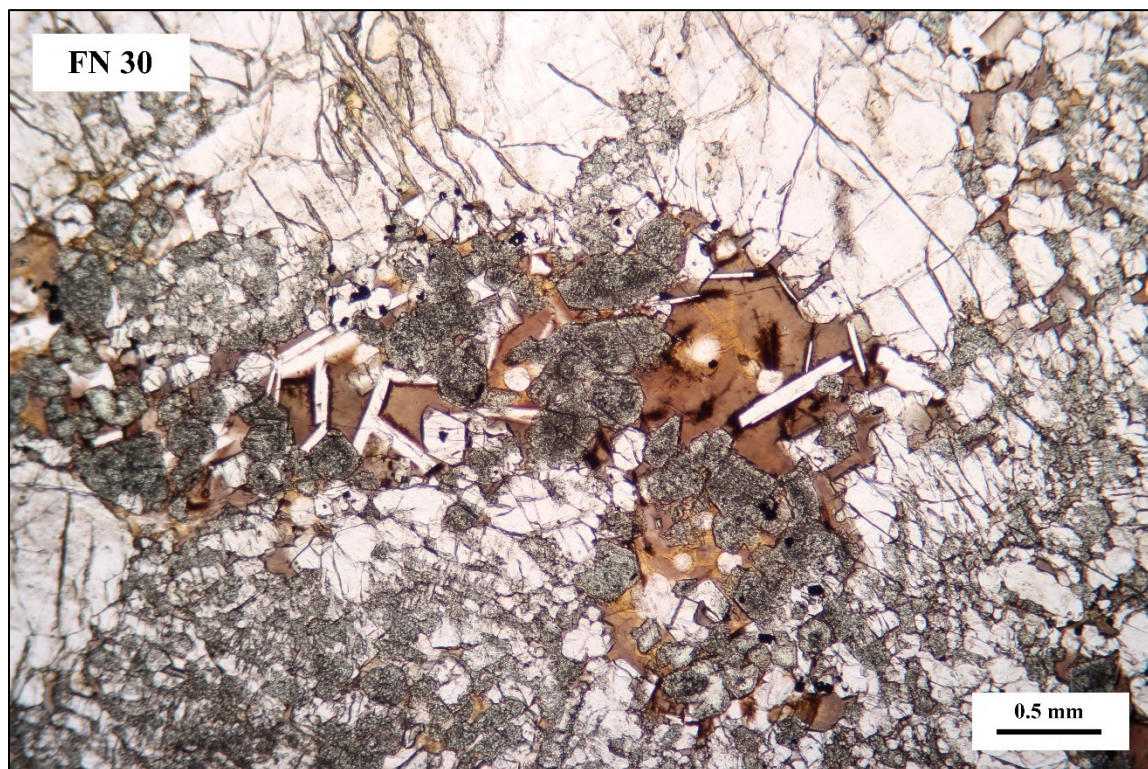


Figure 7: Thin section image of sample FN30. Notice the brown glass with magmatic euhedral crystals inside and the large anhedral mantle olivine crystal above the glassy patch.

As previously underlined, all samples have diffuse glass which is brown in colour (Fig.7), forming extended patches or small pockets (as the one in Fig.8D). In the latter case, they tend to be concentrated at junctions among grains having a more defined and rounded shape. It sporadically displays the presence of gas bubbles, now fulfilled by zeolites; otherwise, there is no evidence of

alteration. They always show evidence of crystal fractionation. As a matter of fact, inside the glassy patches, clinopyroxene and olivine are always present; spinel and plagioclase have been observed in all the selected xenoliths, but they appear absent in some of the glassy patches while in others are quite abundant. Finally, among the accessory phases, have been observed apatites (except for FN18) and very few hornblendes (sample FN14). Clinopyroxene generally appears as strongly poikilitic and pale green (optically diopside) which occasionally evolved in a pink rim (optically Ti-augite; Fig.8A). The plagioclase is variably abundant inside glassy patches showing different grain sizes and, in some occurrences, it shows direct zonation. Spinel is generally abundant and sometimes is included in magmatic olivine or in clinopyroxene, but not in plagioclase.

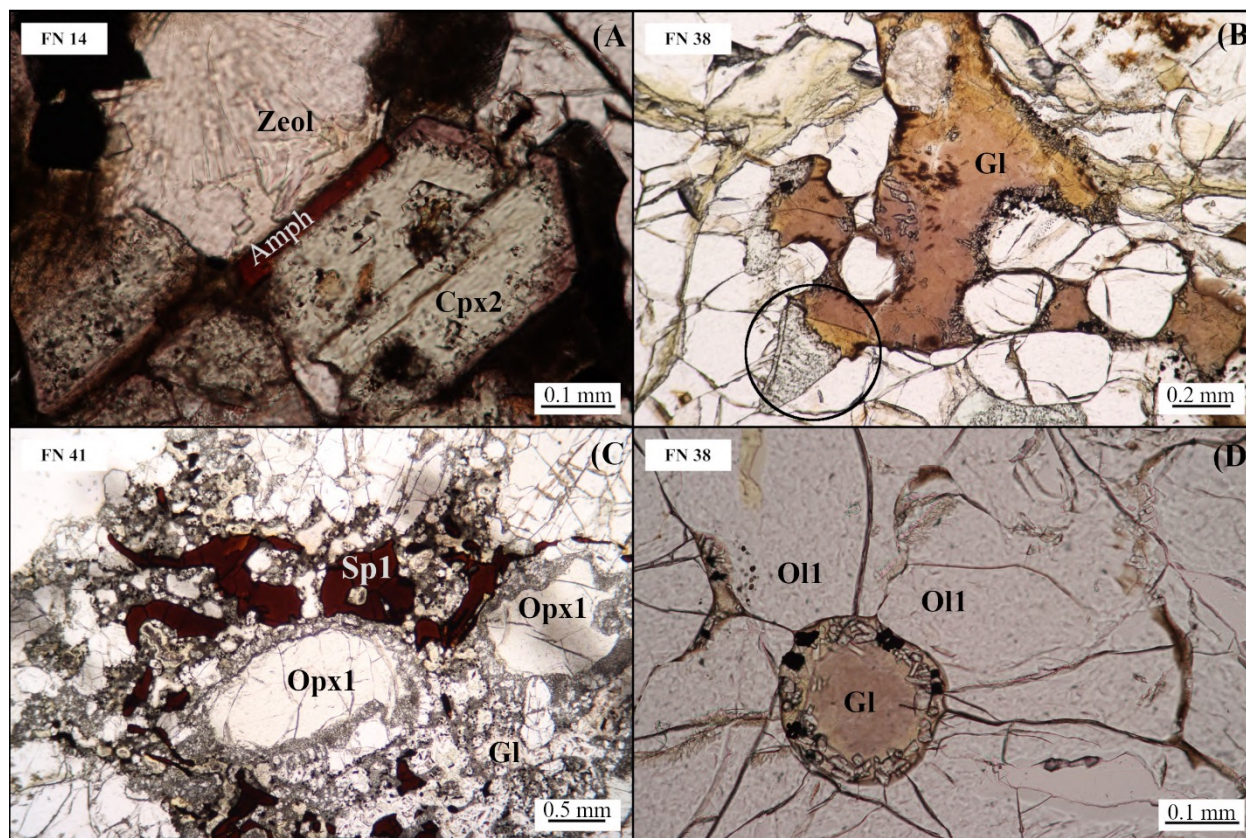


Figure 8: microphotographs obtained through a polarized optical microscope. A) zoned clinopyroxene (Cpx2), amphibole (Amph) and a zeolite (Zeol) all crystallized inside a glassy patch; B) glass (Gl) in sample FN38, circle highlighting a mantle clinopyroxene partially resorbed and now zoned as a consequence of reaction with the glass; C) mantle spinel (Sp1) and partially resorbed mantle orthopyroxene (Opx1) with reaction coronae; D) small glassy patch (Gl) surrounded by mantle olivines (Ol1).

5. X-ray computed microtomography

Considering the X-ray micro-CT analysis, as previously resumed in the methods section of this thesis, we worked with incremental steps of resolution, starting with a conventional system at 23.33 μm of pixel size (step A in Table1) and moving on to steps B, C and D. In the analyses of the samples have been followed the methodology specifically studied and reported in the appended manuscript (AppendixA; Venier et al., submitted to Geoscience Frontiers). As shown in Table1, all the five mantle xenoliths were analysed throughout conventional X-ray μ -CT systems and synchrotron radiation-based X-ray near-parallel beam system. In the 3D models obtained after pre-processing operations, we segmented, according to petrographic evidence: spinel, glasses and silicates.

In steps A and B we characterized quantitatively the segmented volumes, through a connected component analysis for the isolated phases and with a skeleton analysis for the interconnected volumes (i.e. glasses), as previously explained in the methods section. In Table2 we summarized the skeleton analysis results, while the connected component analyses are attached in AppendixB. For all the sample the connectivity density suggests that the glass is continuously filling the xenoliths and this supports the idea that, at least for each sample, one melt percolated the entire analysed volume.

Sample	Step	Volume	Surface	Feret diameter (μm)		Edges/ Vertices	Connectivity density
		(μm^3)	(μm^2)	Min	Max	ratio	(μm^{-3})
FN14	B	$4.00 \cdot 10^{10}$	$1.43 \cdot 10^9$	$8.22 \cdot 10^3$	$2.86 \cdot 10^4$	0.92	$-2.91 \cdot 10^{-7}$
FN18	B	$4.85 \cdot 10^{10}$	$3.93 \cdot 10^9$	$1.40 \cdot 10^4$	$2.31 \cdot 10^4$	0.89	$-1.29 \cdot 10^{-6}$
FN30	B	$1.45 \cdot 10^{10}$	$5.42 \cdot 10^8$	$1.08 \cdot 10^4$	$2.79 \cdot 10^4$	0.88	$-2.92 \cdot 10^{-7}$
FN38	A	$9.12 \cdot 10^{10}$	$2.07 \cdot 10^9$	$1.62 \cdot 10^4$	$5.26 \cdot 10^4$	0.92	$-7.23 \cdot 10^{-8}$
FN38	B	$8.04 \cdot 10^9$	$7.81 \cdot 10^8$	$8.33 \cdot 10^2$	$1.51 \cdot 10^4$	0.95	$-3.50 \cdot 10^{-6}$
FN41	B	$2.75 \cdot 10^{10}$	$9.27 \cdot 10^8$	$1.08 \cdot 10^4$	$2.76 \cdot 10^4$	0.88	$-2.42 \cdot 10^{-7}$

Table 3: results of the skeleton analyses for all the samples investigated.

5.1 FN14

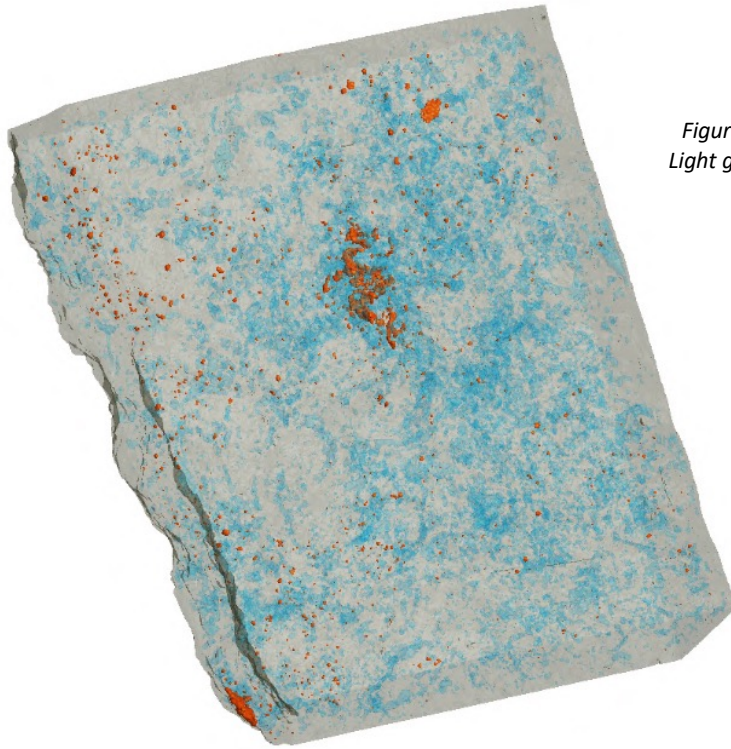


Figure 9: 3D model obtained at step B for sample FN14. Light grey the xenolith segmented, in blue the glass and in orange the spinel. 1168x564x1251 voxels.

For sample FN14 a total volume of $2.31 \cdot 10^{12} \mu\text{m}^3$ was analysed in step B (17.5 μm of pixel size). Obtained 3D model and segmented phases are visible in Fig.9. Segmenting spinel and glasses we found out they occupy, inside the xenolith volume, the 0.06% and 1.74% respectively. Spinel has mainly a subrounded shape, as connected components analysis underlined (see AppendixB) and is scattered inside the volume, with the exception of three larger clusters, visible in Fig.9. Glass is fully scattered inside the sample, without any alignment or preferred orientation, and always found in concomitance with spinel. Skeleton analysis highlighted a high level of connectivity, testified by very low connectivity density values (see Table2 for details).

Synchrotron-based analysis of steps C and D (2.5 and 0.9 μm of pixel size respectively) allow us to clearly define the texture of spinel, which follow the glass in all the xenolith and is often present in a fully octahedral shape (Fig.10B). Only some of the smallest individuals are anhedral or subrounded, with the larger crystals localized inside the larger glassy patches. Even glass appears clearer at this resolution. It is evident looking at the 3D model of Fig.10A how it is not only arranged in large patches but occupies even fractures and the intercrystalline spaces, defining a thin film, visible as flat surfaces in the segmented glass volume of Fig.10A, that surrounds the silicate phases forming the xenolith.

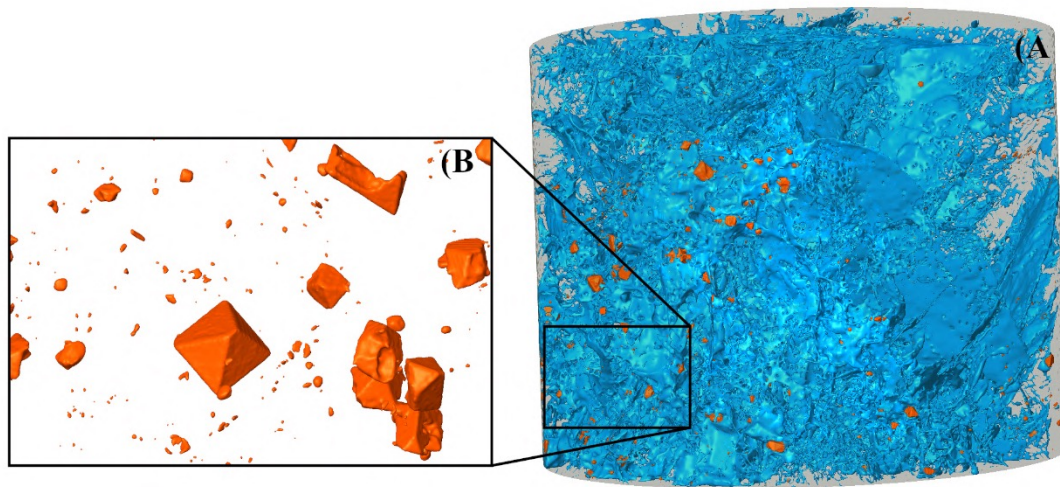


Figure 10: 3D model of sample FN14 obtained in step C. A) In light grey the silicates, in orange the spinel and in blue the glass. B) zoom on the spinel in a selected volume, without showing silicates or glasses. 1681x1597x1784 voxels.

5.2 FN18

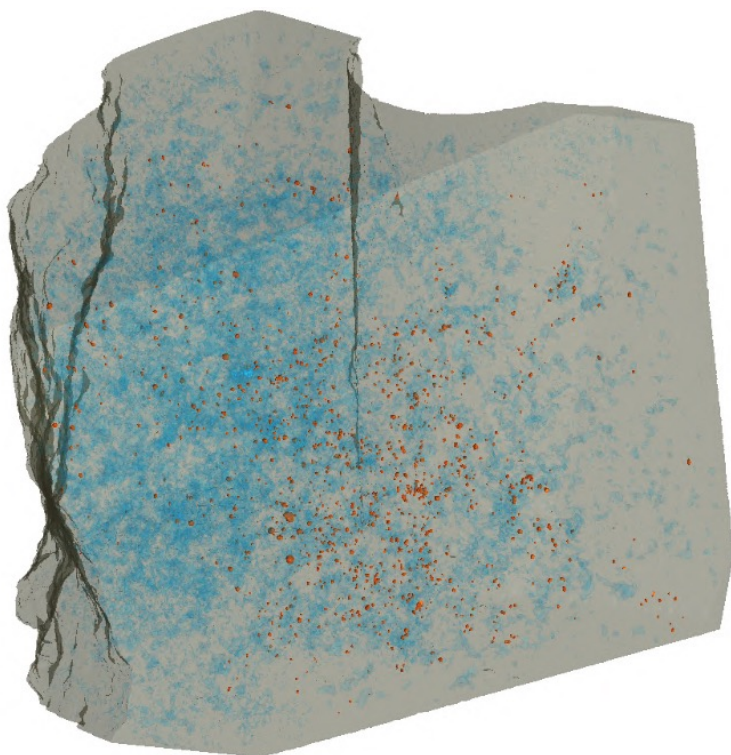


Figure 11: 3D model of sample FN18, obtained in step B. In light grey the silicates, blue the glasses and orange the spinel. 1852x1802x1271 voxels. The right side of the sample appears as less filled by glass, only because of is thinner with respect to the left side.

Step B in sample FN18 allows to analyse and segment a total volume of $3.79 \cdot 10^{12} \mu\text{m}^3$ at a pixel size of $12.5 \mu\text{m}$, in which, after the segmentation, $3.70 \cdot 10^8 \mu\text{m}^3$ appear as spinel and $4.85 \cdot 10^{10} \mu\text{m}^3$ as glass (Fig.11). Spinel does not show large clusters and is present only as small subrounded crystals with various dimensions. As for sample FN14, we performed a connected component analysis and the results are summarized in AppendixB. The glass is fully scattered inside the xenolith and to better understand its interconnection we performed a skeleton analysis (Table2), in which results that the glass has a high level of connections, as in sample FN14, showing a connectivity density of $-1.29 \cdot 10^{-6} \mu\text{m}^{-3}$.

Steps C ($2.5 \mu\text{m}$ of pixel size) and D (pixel size: $0.9 \mu\text{m}$) evidenced some similarities with sample FN14, as the spinel appears fully crystallized in euhedral to subhedral shape, with few crystals showing a rounded or anhedral habitus (Fig.12B). Even the glass, at the highest resolution ($0.9 \mu\text{m}$), shows the same behaviour as in xenolith FN14, fulfilling fractures and intergrain spaces.

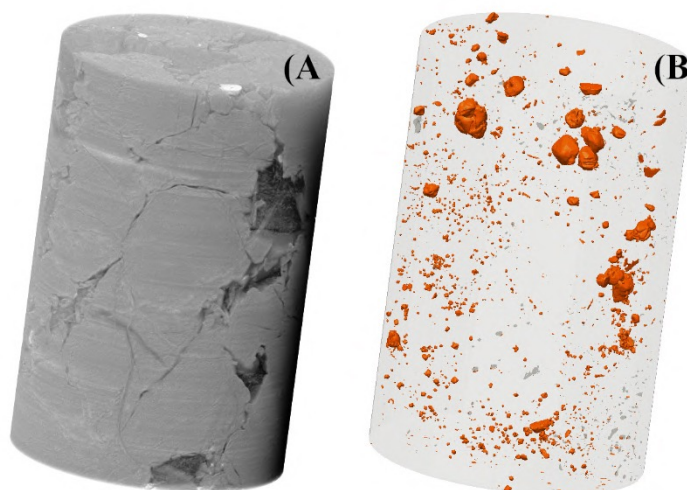


Figure 12: A) 3D model of sample FN18 obtained in step D. B) spinel segmented in orange and the silicates in light grey. 1377x1369x2048 voxels.

5.3 FN30

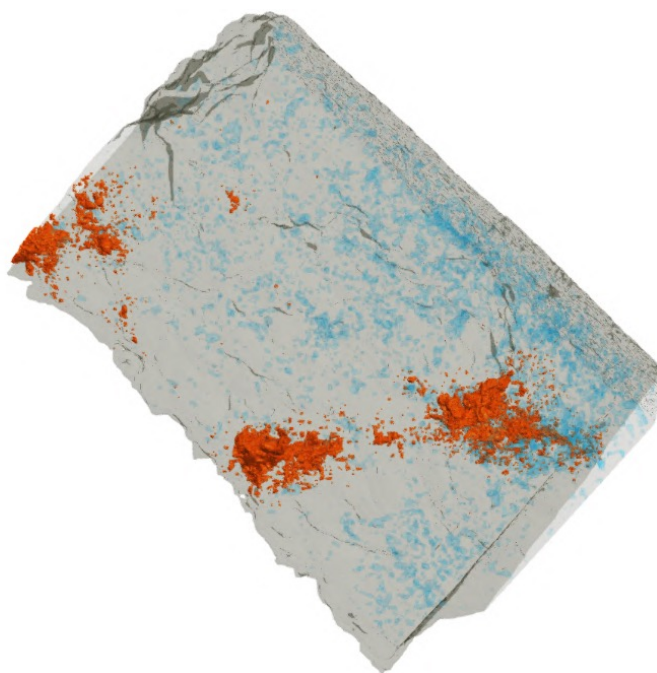


Figure 13: 3D model of sample FN30, obtained in step B. In light grey the silicates, blue the glasses and orange the spinel. 1308x784x1271 voxels.

In step B (pixel size: 17.5 μm) of sample FN30, $2.17 \cdot 10^{12} \mu\text{m}^3$ of xenolith were imaged, with $8.35 \cdot 10^9 \mu\text{m}^3$ of spinel and $1.45 \cdot 10^{10} \mu\text{m}^3$ of glass. In this sample, 7 main clusters of anhedral spinel are present, with several smaller and rounded crystals around (Fig.13). As visible in Fig.13 the clusters (thin section suggests they are mainly Cr-spinel) appear concentrated in two main layers. It was possible to fully characterize spinel with connected component analysis, results are summarized in AppendixB. Glass on the other hand is, again, fully scattered inside the sample, forming both small and larger patches. Skeleton analysis allows quantifying the interconnection of the glass volume, which appears high even in this sample (connectivity density in Table2).

Steps C and D (pixel sizes of 2.5 and 0.9 μm respectively) show some differences with respect to the previous xenoliths (FN14 and FN18), as here spinel shows always a skeletal texture with crystals miming an octahedral shape, but with a lot of void spaces inside. In step D we focused on a single glassy patch, segmenting a crystal of magmatic olivine inside it. As visible in Fig.14 the olivine is hosting some skeletal spinel crystals and the glass that surrounds the olivine is present both inside the crystal and inside the spinel.

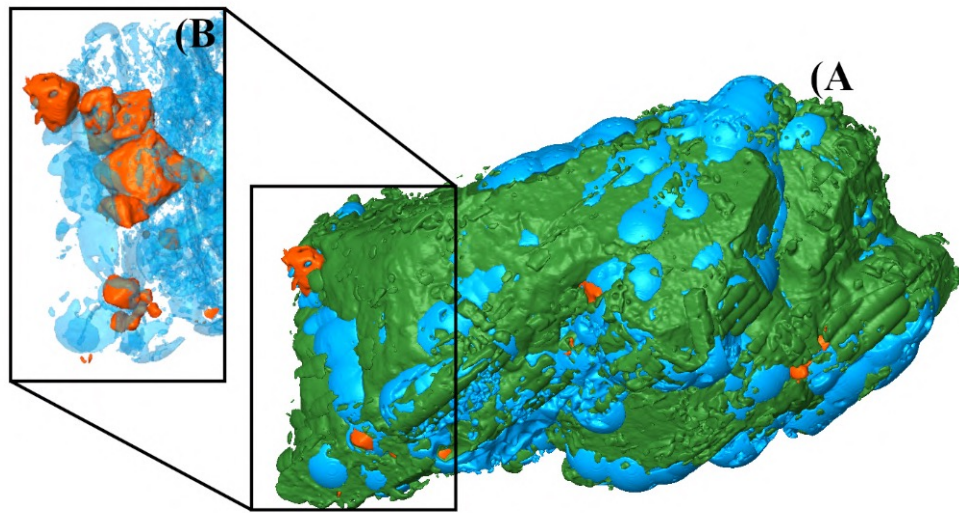


Figure 14: A) in green a segmented crystal of olivine from FN30 in step D. In blue the segmented glass and in orange the spinel. B) zoom on some included spinel crystals, without showing the hosting olivine. Notice how glass fulfil the voids inside the skeletal texture of spinel. 1845x1865x2048 voxels.

5.4 FN38



Figure 15: 3D model obtained in step A for sample FN38. 1121x764x2151 voxels, spinel segmented in orange, glass in blue.

With the aim to characterize the glass texture in at least one whole sample, we obtained the possibility to collaborate with the International Centre for Theoretical Physics (ICTP) and to image the entire mantle xenolith FN38 at a low resolution ($6.02 \cdot 10^{12} \mu\text{m}^3$ of xenolith; StepA in Table1). The glass in the intergrain spaces (seen in the previous samples) at this resolution is not resolvable, but it is possible to understand its abundance and its randomly scattering inside the xenolith (Fig.15). Results are fully treated in the appended manuscript (AppendixA). To define the interconnectivity of glass we performed a skeleton analysis on the segmented volume ($9.12 \cdot 10^{10} \mu\text{m}^3$) obtaining a skeleton with 80'844 vertices and 74'250 edges, that identifies a connectivity density of $-7.23 \cdot 10^{-8} \mu\text{m}^{-3}$. At this low resolution, only the larger clusters of spinel were visible. Overall, the segmented phases were silicates (98.500%), glass (1.494%) and spinel (0.006%). It was possible to characterize spinel through a connected component analysis and define its orientation and aspect ratio, results are summarized in AppendixB.

Step B focused on the central part of sample FN38, reaching a pixel size of $6.7\ \mu\text{m}$ and analysing a total volume of $8.00 \cdot 10^{11}\ \mu\text{m}^3$. No further textural details were noted for spinel, as it appears the same as in step A, grouped in clusters. To determine quantitatively its orientation and shape we performed a connected component analysis as for the other samples (AppendixB). Glass is again scattered inside all the xenolith and we investigate its interconnection throughout a skeleton analysis, as summarized in Table2.

Step C focused on the inner part of the volume analysed in step B, imaging a total volume of $9.64 \cdot 10^{10}\ \mu\text{m}^3$ with a pixel size of $2.5\ \mu\text{m}$. The main improvement here is the possibility to see the microlites of spinel inside the glassy patches and some vesicles filled with a material similar in density to the silicic glass (possibly zeolites that were visible with the optical microscope), which were undetectable or poorly detectable at lower resolutions and visible only in the thin section. A selected volume of interest was imaged with a pixel size of $0.9\ \mu\text{m}$ (step D). Here it was possible to better characterize the low-density volumes. In fact, there are not only glassy patches but also tiny films, as in all the previous samples, occupying the intergrains spaces (Fig.16).

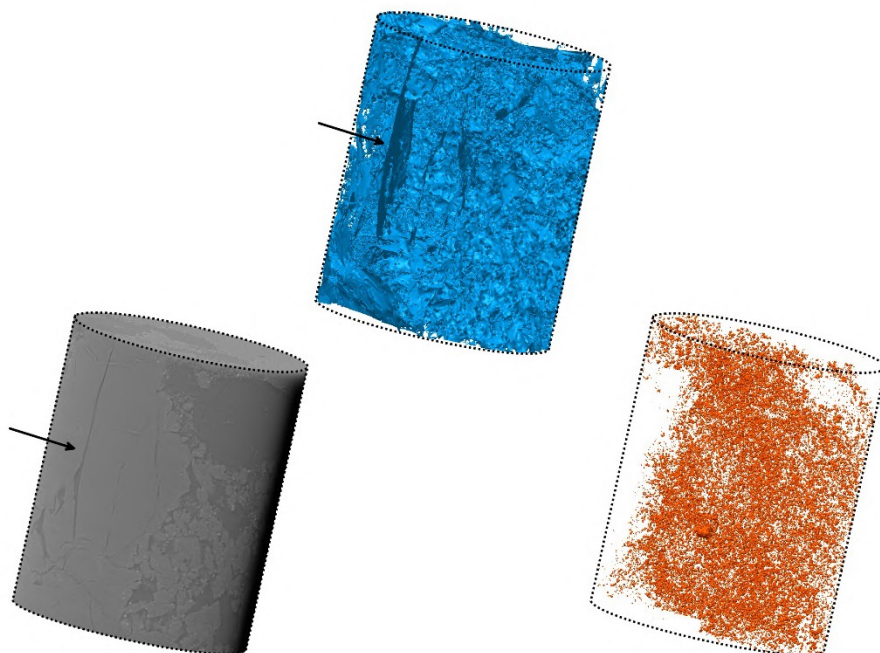


Figure 16: 3D reconstruction of a volume of interest in mantle xenolith FN38 obtained at step D, $1825 \times 1833 \times 2048$ voxels. Spinel segmented in orange, glass in blue. Arrows pointing at glass filling an intergrain space.

5.5 FN41

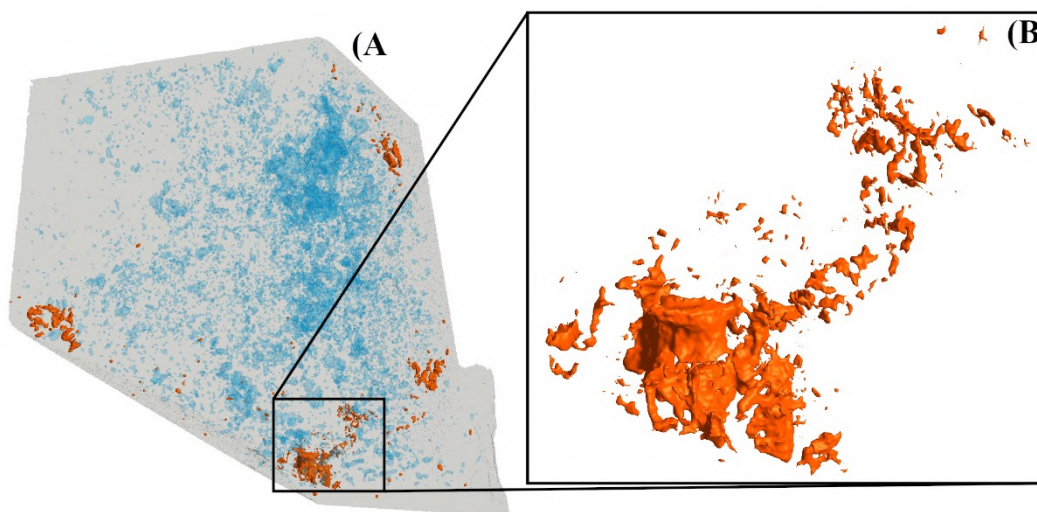


Figure 17: A) 3D model obtained at step B for sample FN41. In light grey the xenolith segmented, in blue the glass and in orange the spinel. 1327x1210x1270 voxels. B) zoom of a spinel cluster, without showing glasses or silicates.

For sample FN41, at a resolution of $17.5\ \mu\text{m}$ (step B, in Table1), a total volume of $2.13 \cdot 10^{12}\ \mu\text{m}^3$ was imaged. We segmented $9.97 \cdot 10^8\ \mu\text{m}^3$ of spinel and $2.75 \cdot 10^{10}\ \mu\text{m}^3$ of glass. In this sample, the glass appears as concentrated in 6 to 9 larger patches and this is the only sample in which the highest density of glasses are not located in correspondence of spinel. Connectivity has been studied through skeleton analysis as summarized in Table2. Spinel is present in both small rounded crystals and large clusters. As visible in Fig.17, the clusters show the typical holly-leaf shape attributed to mantle spinel in literature (Mercier & Nicolas, 1975).

Steps C and D (2.5 and $0.9\ \mu\text{m}$ of pixel sizes respectively) showed the same features of mantle xenolith FN38: the presence of several small and rounded spinel crystals, not detectable at a lower resolution, always inside glassy patches. The glass is, once again, present not only inside the patches but even in fractures and in the intergrain spaces.

6. Mineral chemistry

As done with the petrography, we decided to separate mantle minerals from magmatic ones, labelling with number 1 mantle phases, as they are the first ones to have been formed, and with number 2 all the minerals crystallized inside glassy patches and characterized by a euhedral habitus. This distinction is only based on petrographic evidence. Chemical differences between the two groups (or lack of differences) will be discussed further in the text. In all the graphs, data of mantle minerals and magmatic phases are coloured in blue and red, respectively. Moreover, as some phases appeared zoned even under the optical microscope, we took, when possible, a spot on the core and another one on the rim of every analysed crystal.

6.1 Spinel

Spinel occurs as anhedral in shape, considering the petrographic observations, only in samples FN30 and FN41, thus we analysed these occurrences in both cores and rims. For what concerns magmatic euhedral spinels, due to their small dimensions, we analysed 23 cores and 3 rims.

Considering major elements analyses, they show a composition with an Mg# ($\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$) in the range 0.28-0.78 and a Cr# ($\text{Cr}/(\text{Cr}+\text{Al})$) in the range 0.26-0.66 as visible in Fig.18. Considering the mantle phases, they plot over the composition of the Sp DMM (Workman & Hart, 2005) and, going from core to rim, it is possible to observe a decrease in Mg# and an increase in Cr#.

In the ternary diagram of Fig.19, samples are prevalently in the field of spinel from mantle xenoliths, with few plotting inside the field of spinel from ocean-floor peridotites. According to Barnes & Roeder (2001), all the spinel plot along with two main trends: one exactly coincides with the Fe-Ti trend, while the other may be located between the Cr-Al and the Rum trends. TiO_2 content is quite variable, ranging from 0.12 wt% to 21.2 wt%. Assuming that the TiO_2 represents the ulvospinel component, this varies in our samples from 0% to more than 50%. In the diagram in Fig.20, all the samples plot in the magmatic field, notably also the “mantle” spinel plots close to the other ones.

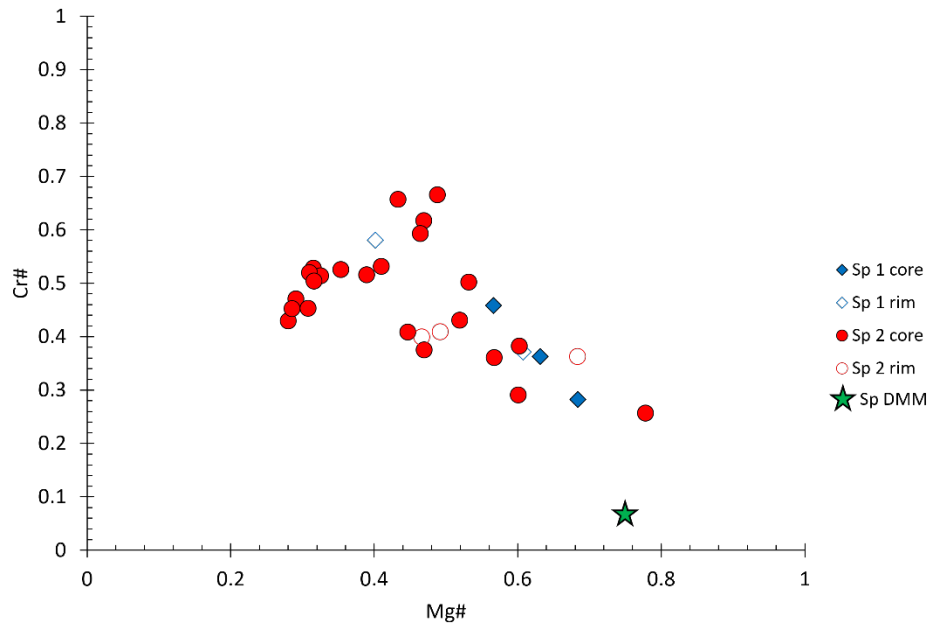


Figure 18: Mg# vs. Cr# for all the spinels analysed. Composition of a spinel calculated for the depleted MORB mantle (DMM; Workman & Hart, 2005) is plotted for comparison.

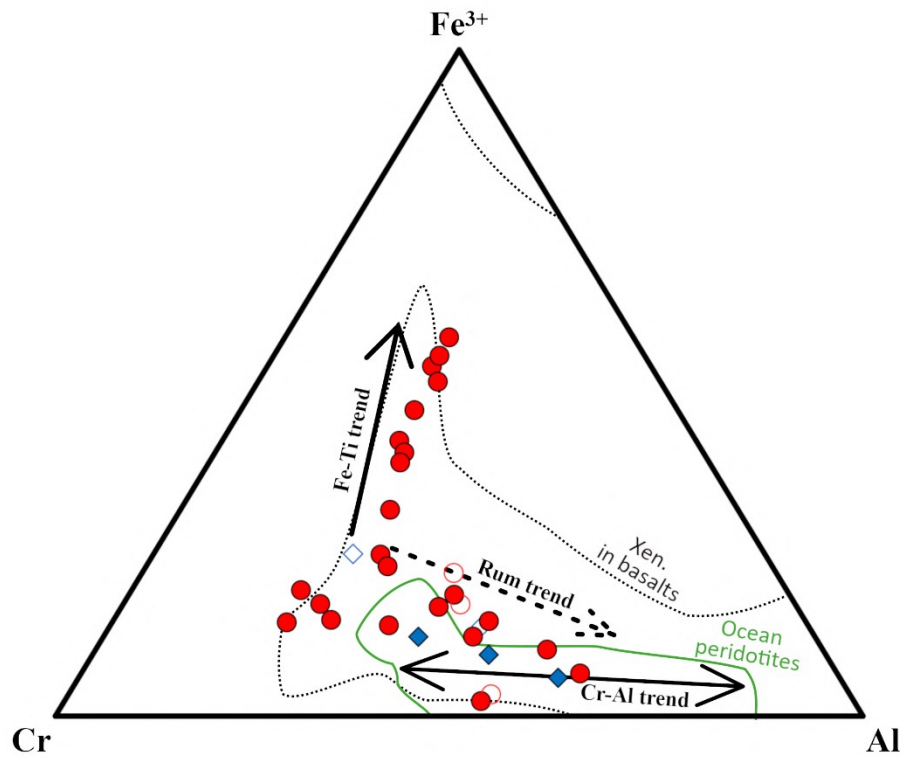


Figure 19: ternary classification diagram for spinel from Barnes & Roeder (2001). Arrows showing the different trends. As solid green line the field of spinel from ocean-floor peridotites, dotted black line delimiting field of spinel from xenoliths in basalts and alkali basalts. Symbols as in Fig.18.

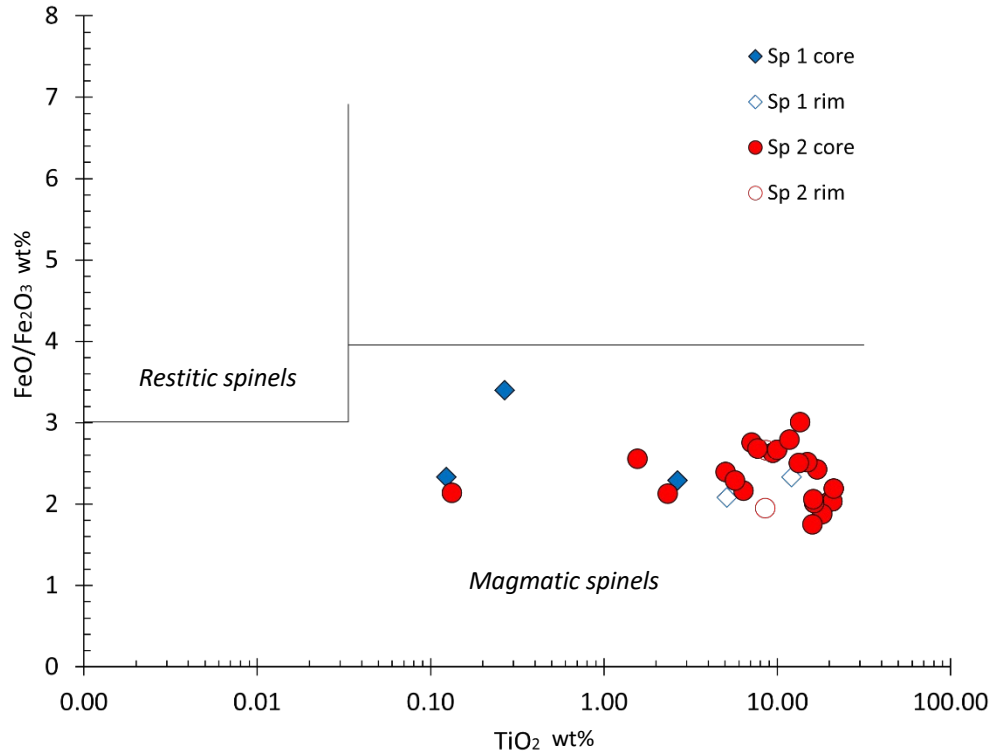


Figure 20: genetic discrimination diagram between restitic spinels and magmatic ones, fields are from Lenaz et al. (2000). Elements concentrations given in wt%.

Considering the REE content of the spinel analysed (see Fig.21A), our samples show an enriched LREE (Light Rare Earth Element) pattern with respect to M- and HREE (Medium and Heavy Rare Earth Element, respectively), in several cases the M- and HREE are below the detection limit. Where possible, the analysed Sp appear as enriched with respect to Sp DMM (calculated by Workman e Hart, 2005) and also to the chondrite (Boynton, 1984) showing an OIB-like pattern. Looking at La and Ce (strongly twins elements) concentrations, they individuate a good positive correlation, with an R^2 value of 0.99 (Fig.21B).

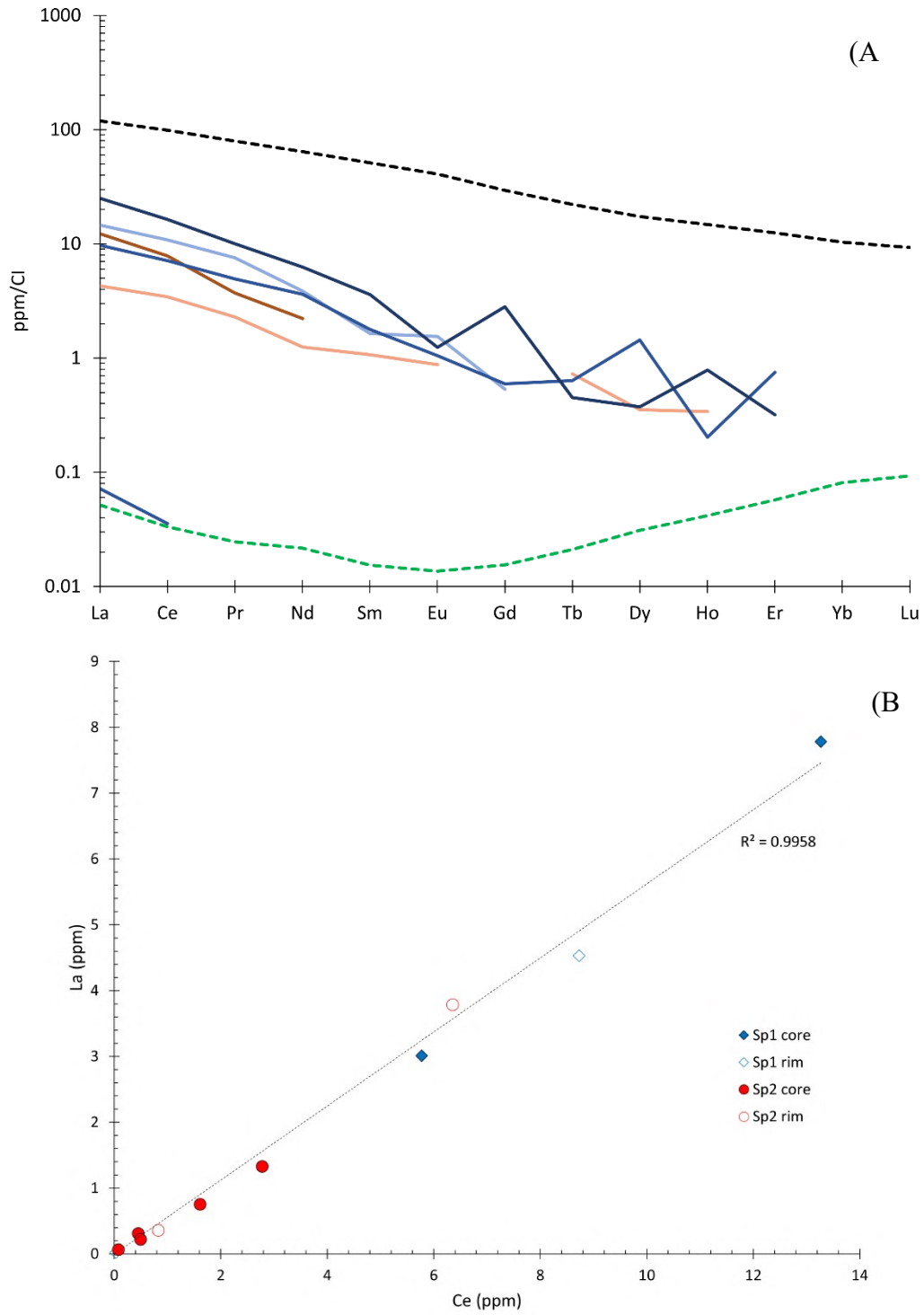


Figure 21: A) REE pattern of our anhedral spinels in blue and magmatic ones in orange. As dotted green line the Sp DMM from Workman & Hart (2005), dotted black line the OIB composition from Sun & McDonough (1989). Data normalized to the chondrite from Boynton (1984). B) Ce vs. La values for our spinels. Concentrations expressed in ppm.

6.2 Olivine

We analysed 34 olivines, 21 of which as mantle olivine and 13 as magmatic crystals. The first group has Forsterite ($Fo = (Mg/(Mg+Fe^{2+}+Mn))*100$) values ranging between 85.5 and 90.5 for the cores and 82.5-90.0 for the rims, with the exception of sample FN18 which has Fo values systematically lower ($79.6 < Fo < 80.2$ for cores; $78.9 < Fo < 80.0$ in the rims) as visible in AppendixD. Magmatic crystals have Fo values between 79.5 and 88.6 for cores and rims, with FN18 showing lower values of $79.5 < Fo < 81.3$. It is worth noticing that for Ol crystals in glassy patches, there are few to no differences between cores and rims concerning Fo, while there are differences for mantle olivines, with the lower values registered by rims.

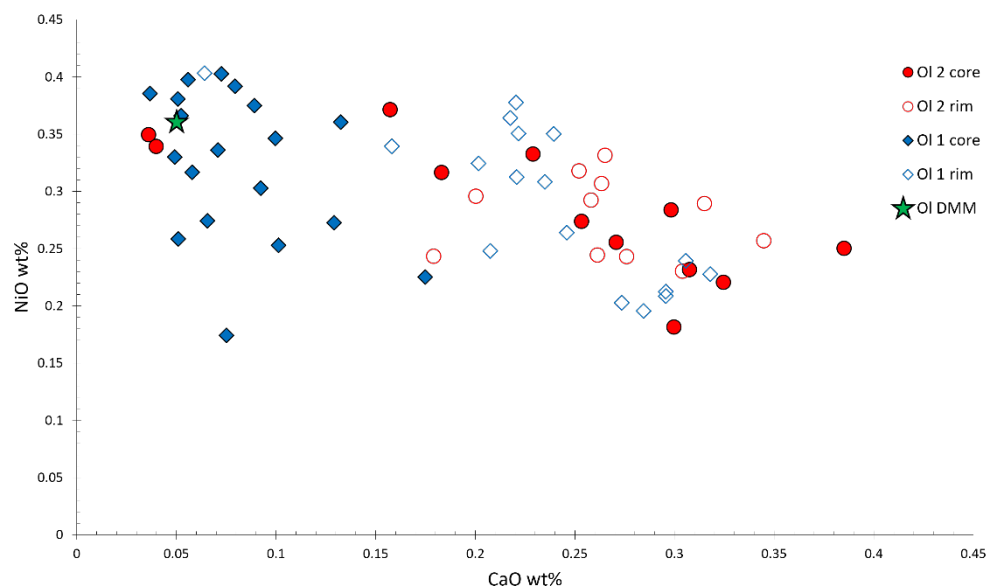


Figure 22: CaO vs. NiO diagram showing the analysed olivines. Plotted values in wt%. Composition of calculated olivine for a DMM from Workman & Hart (2005).

In Fig.22, which shows the NiO wt% vs. the CaO wt% of our samples, NiO values are between 0.17 and 0.40 wt% in mantle olivines, displaying the higher concentrations in the cores with respect to rims (0.32 and 0.29 as average values, respectively), while on magmatic olivine NiO is comprised between 0.18 and 0.37 wt%. On the contrary, considering the CaO content, mantle Ol cores have the lower values ($0.04 < CaO < 0.17$ wt%) with respect to rims ($0.06 < CaO < 0.32$ wt%) and magmatic olivines have even higher values $0.04 < CaO < 0.38$ wt% (0.25 wt% in average). This indicates that the rims of mantle olivines plot in the same field of the magmatic ones. That

behaviour is visible in the traverse that we have done in two mantle olivine, starting from the core of crystals and going to the rims in contact with glassy patches. As visible in Fig.23, from core to rim there is a decrease in the MgO content with an increase in FeO_{tot} and CaO.

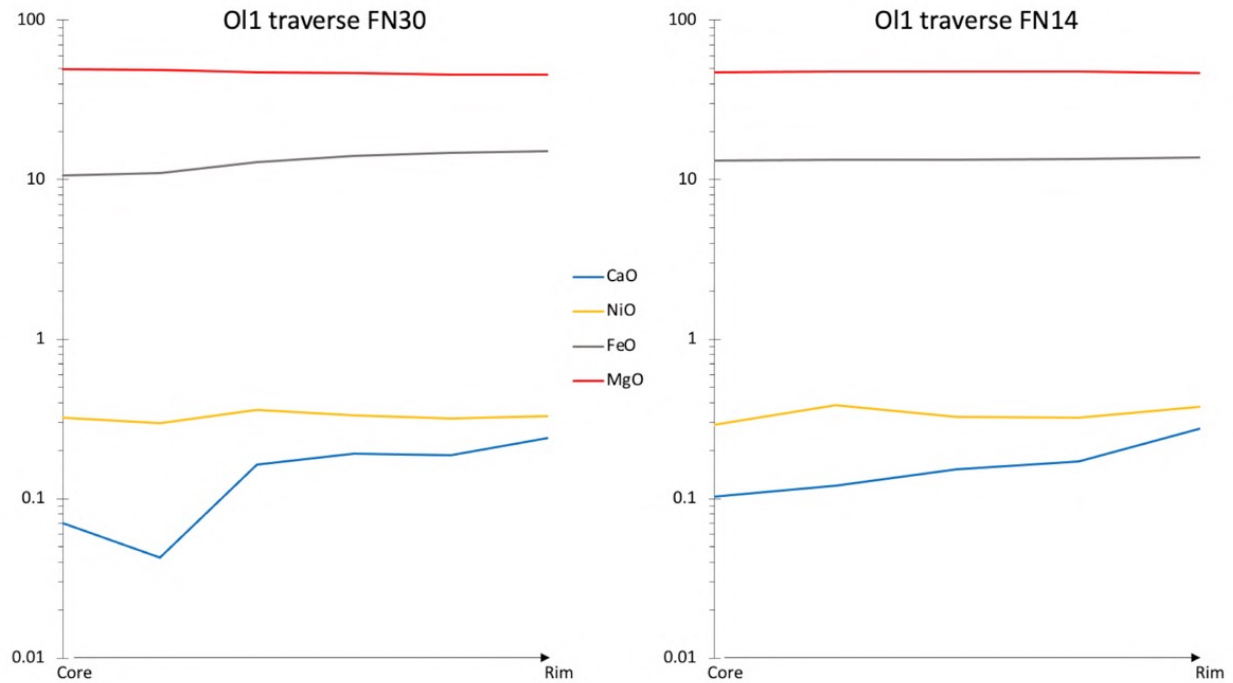


Figure 23: traverse made in two mantle olivine crystals in contact with glassy patches. Oxides contents in wt%.

REE in Fig.24A (mantle olivines) indicate enrichment in comparison with the Ol DMM from Workman & Hart (2005). The majority of analytic spots (both cores and rims) have a flat pattern, similar behaviour is shown by the magmatic samples (Fig.24B), which differ only for having two analyses with an enriched composition with respect to the chondrite (Boynton, 1984).

The same situation is observable in the trace elements spidergrams of Fig.25, with few samples tending towards the OI DMM values, but showing always higher concentrations. In two magmatic occurrences, patterns are strongly enriched. It is interesting to note that the spots that go closer to DMM composition show a positive spike in the lead content.

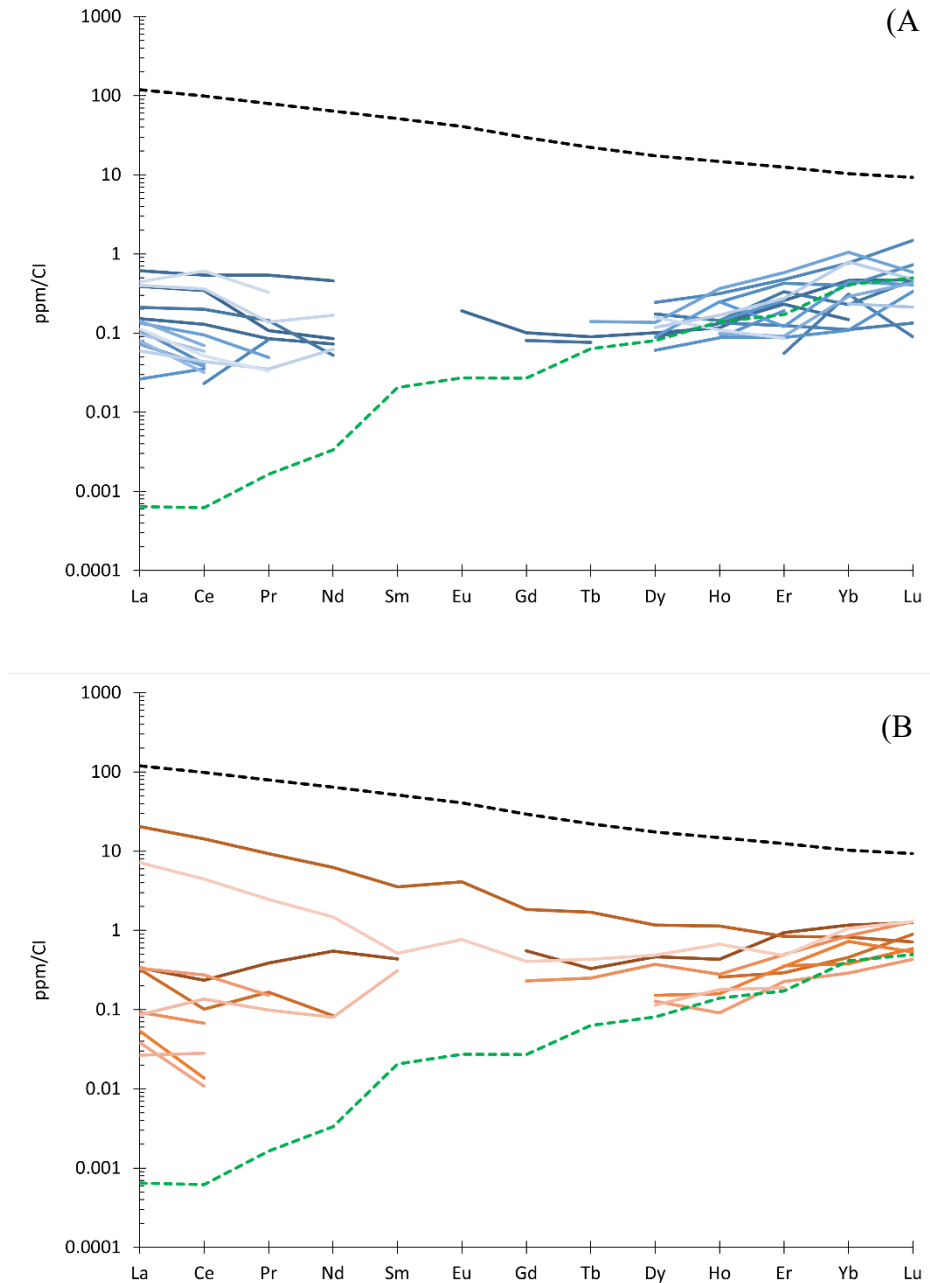


Figure 24: REE patterns, in blue OI1 data and in orange OI2 data. Analyses normalized to the chondrite composition of Boynton (1984). In dotted green line the composition of the OI DMM by Workman & Hart (2005), in dotted black line OIB pattern from Sun & McDonough (1989).

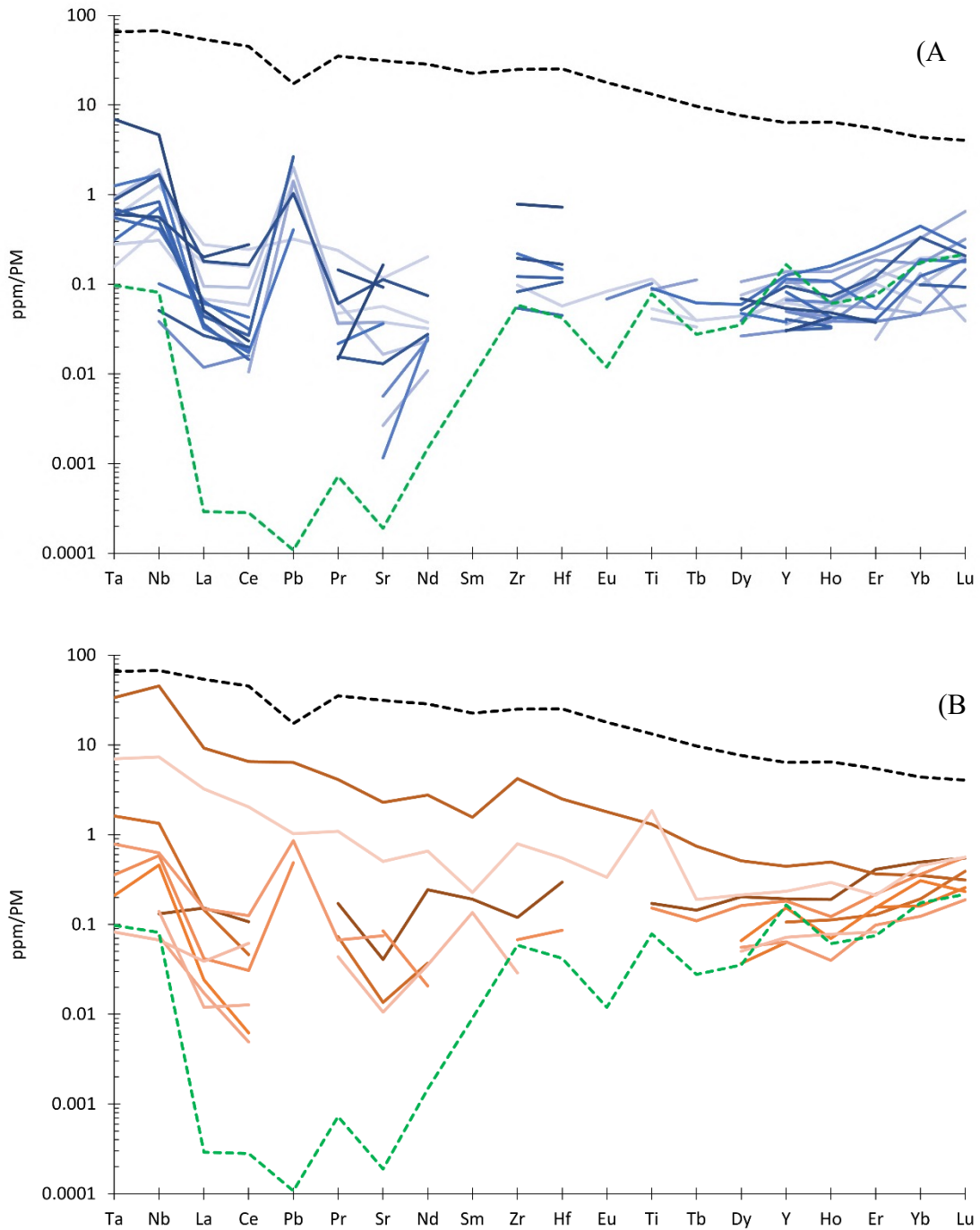


Figure 25: spidergrams with data normalized to the primitive mantle of Sun & McDonough (1989). In blue the mantle olivines, in orange the patterns of magmatic olivines. Dotted green lines represent the composition of OI DMM by Workman & Hart (2005).

6.3 Pyroxene

We analysed 35 pyroxenes, four of which were mantle orthopyroxenes, 10 clinopyroxene petrographically hypothesized as being mantle phases, and 21 magmatic clinopyroxenes crystallized inside glassy patches. As visible in Fig.26, all the Opx are enstatite, while the Cpx show differences in composition between mantle and magmatic crystals. The mantle ones (core), have a composition plotting in the H-Ca augite field, while the rims plot in two distinct fields, one close to their cores the other in the diopside as well as the magmatic ones. Magmatic Cpx have quite the same composition, with some samples forming a possible trend, tending towards the Ca vertex of the diagram. Some analyses are even out of the diopside field, this is an artefact due to the diagram, as all samples need to reach a sum of 100% between the three components to fit in the ternary diagram En-Wo-Fs.

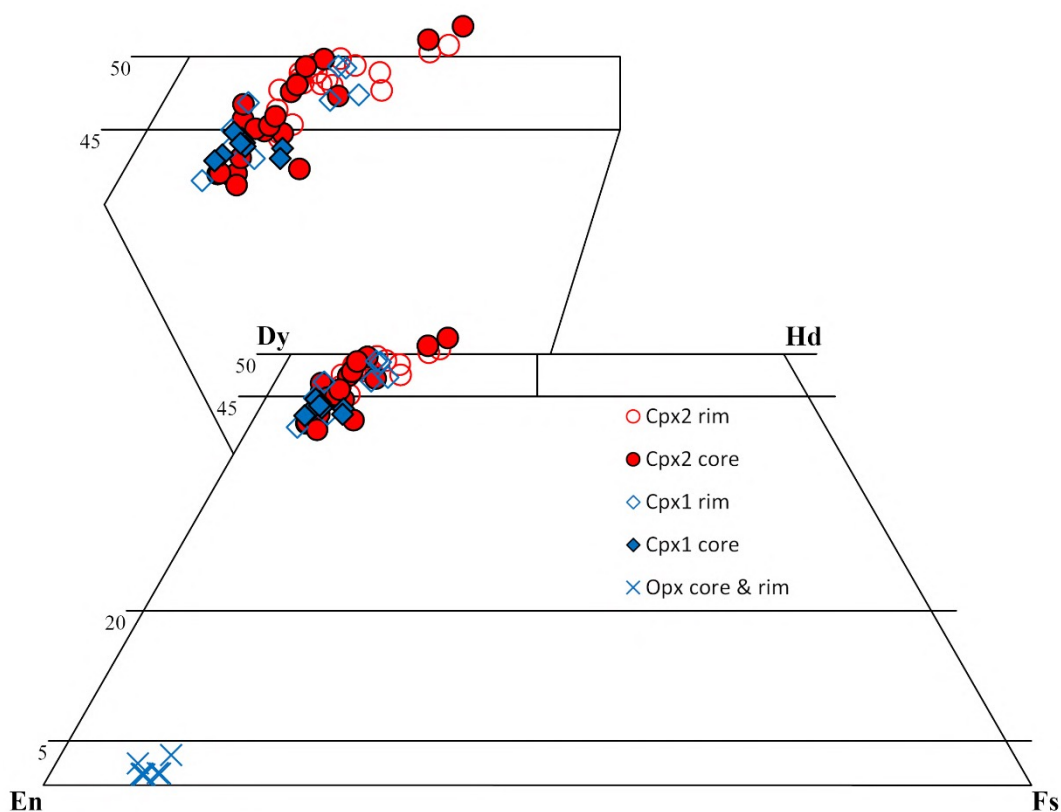


Figure 26: pyroxene classification diagram of Morimoto (1988).

Orthopyroxenes are all mantle phases, as described in the petrography section of this work, and show quite the same composition for cores and respective rims, with the only exception of one Opx from sample FN30, that is partially resorbed and in contact with several olivines and Cpx. That crystal has the highest SiO₂ values (56.14 wt%) in its core and the highest CaO concentrations (1.80 wt%) in its rim. The only other consideration between cores and rims is that in all samples except FN30, Opx has higher MgO content in the rims with respect to cores. This is visible in Fig.27, where the orthopyroxene of sample FN30 occupies the centre of diagrams with Al₂O₃ content of 2.56 wt% for the core spot and 3.11 wt% for the rim. All our analyses display a composition different to the one of the Opx calculated for the DMM by Workman & Hart (2005). Our orthopyroxenes have systematically higher values of MgO (31.6<MgO<34.0 wt%), FeO (5.5<FeO<7.7 wt%) and SiO₂ (54.6<SiO₂<56.1 wt%) and lower of Al₂O₃ (1.52< Al₂O₃<4.51 wt%) and CaO (0.63<CaO<1.8 wt%).

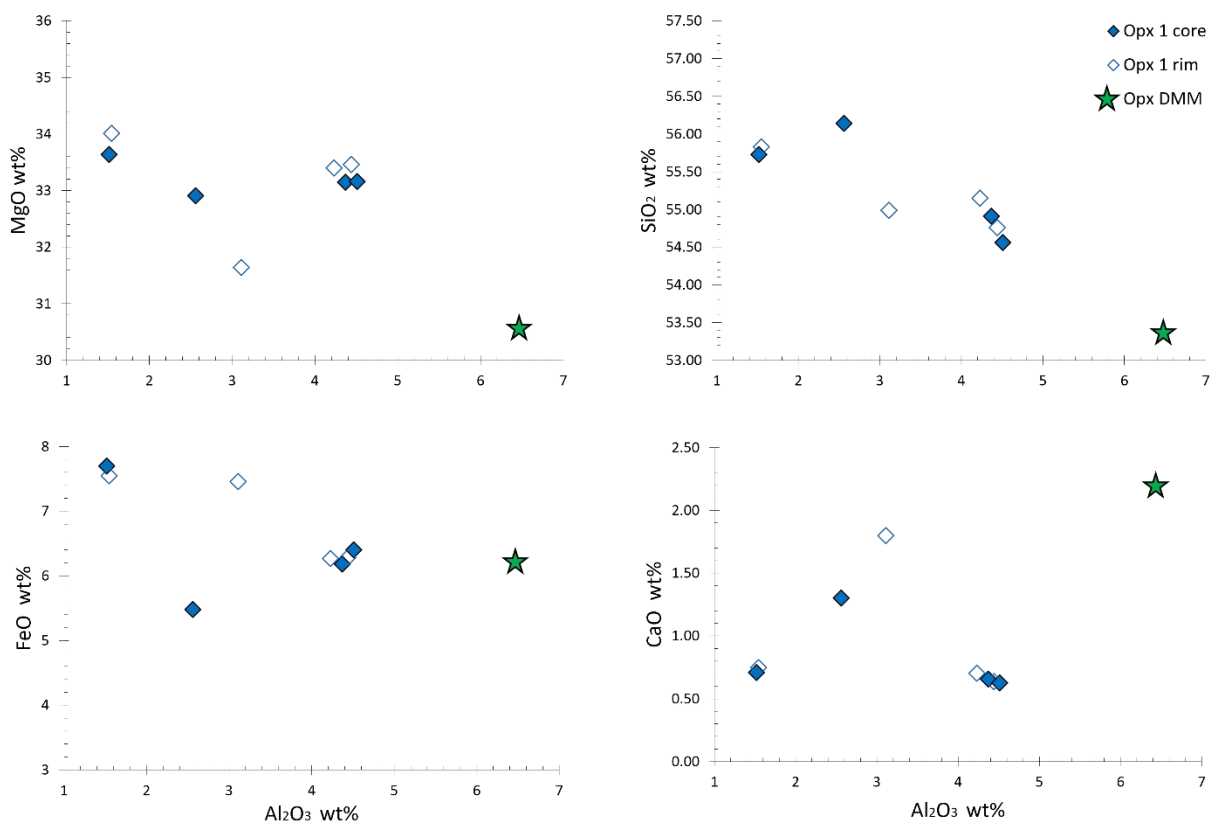


Figure 27: bivariate diagram for some elements in orthopyroxenes. All the oxides content expressed in wt%. Composition of Opx calculated for the DMM by Workman & Hart is plotted for comparison.

We performed 11 different traverses on 6 magmatic clinopyroxenes crystals from xenoliths FN14 and FN18, which are the two thin sections showing the more expressed zonation in Cpx through optical microscope observations. As the BSE image of Fig.28A shows, in addition to the “normal” zonation visible in the rims, Cpx crystals have heterogeneities present as fragments inside their cores. They could represent fragments of mantle clinopyroxenes used by the melt as crystalline seed. This is visible even by the traverse, as there is a progressive change from a mantle-condition to a magmatic one moving from core to rim (for example the decrease in Cr_2O_3 and increase in TiO_2). Indeed, in Fig.28, it is possible to notice the growth of the magmatic Cpx (dotted red line in Fig.39B) over a mantle crystal seed, until it finds another seed (Cpx1 in Fig.28B) that obliges it to expand in that direction (solid red line in Fig.28B).

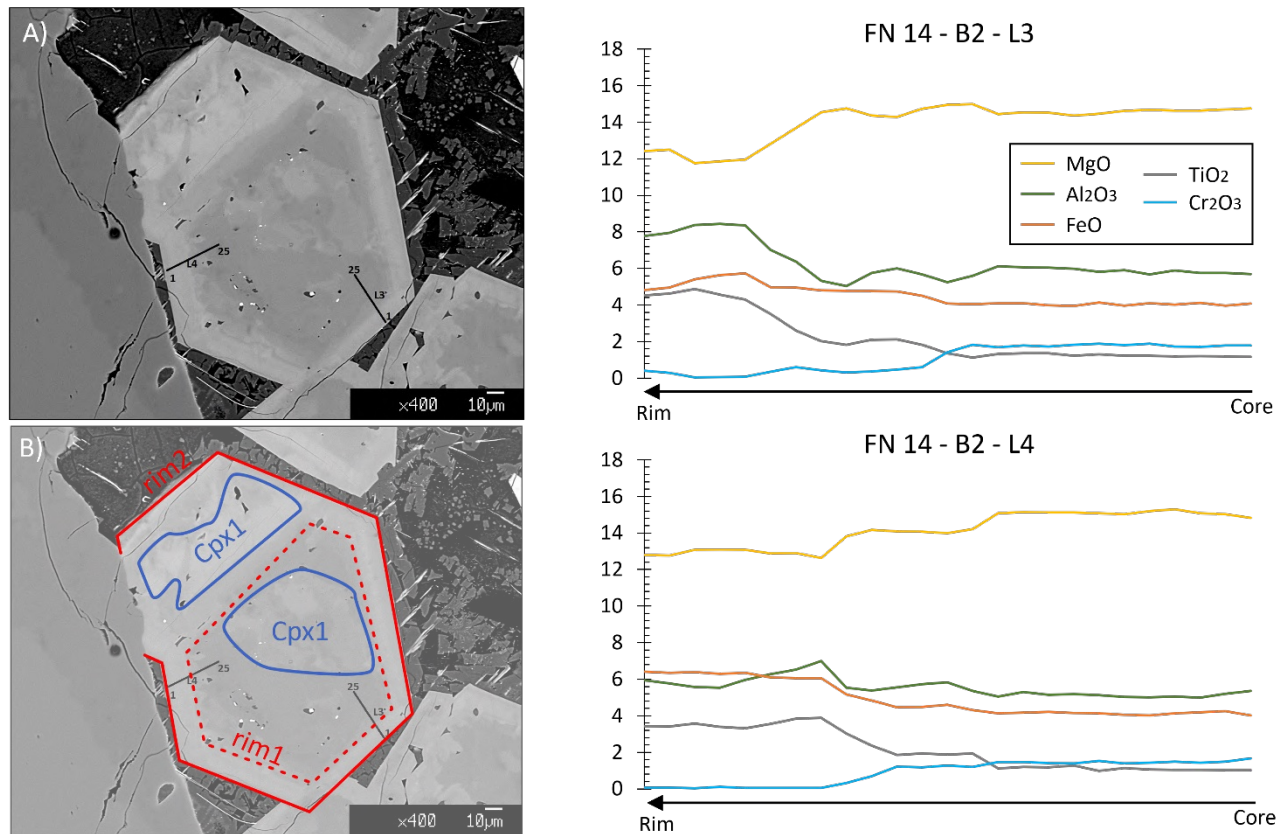


Figure 28: traverses done with EMPA analyses on a magmatic Cpx from sample FN14. On the left backscatter electron image of the clinopyroxene with the traverse as a solid black line; on the right diagrams show the content of the different oxides in wt%.

Considering all the spot analyses, clinopyroxenes show an excess in Al, as testified in Fig.29. This excess led to the saturation of the tetrahedral site, as shown by values always higher than the slope corresponding to site saturation in the Al vs. Si diagram (Fig.29). Considering the diagram of Fig.30, showing the Ti vs. Al^{IV}, it is possible to identify two well distinct groups. At the lower concentrations, we can find both the mantle phases and most of the magmatic cores, while in the second group there are mainly magmatic rims. However, in the CaO vs. Na₂O diagram (Fig.30), the highest Na₂O concentrations (wt%>1) are mainly shown by some cores, both magmatic and mantle ones, the same that in the diagram of Fig.29 show the highest values above the saturation line of the T-site. Because the saturation in the T site could be due to the charge balance, it is related to the variable amount of Ti and Na. This is favoured even by the high presence of Al₂O₃ in the melts, which reach 22 wt% (see the following chapter). Notably, most of the magmatic and mantle cores show the highest Cr concentrations (0.8<wt%<2.2) and among them the highest values are shown by magmatic cores.

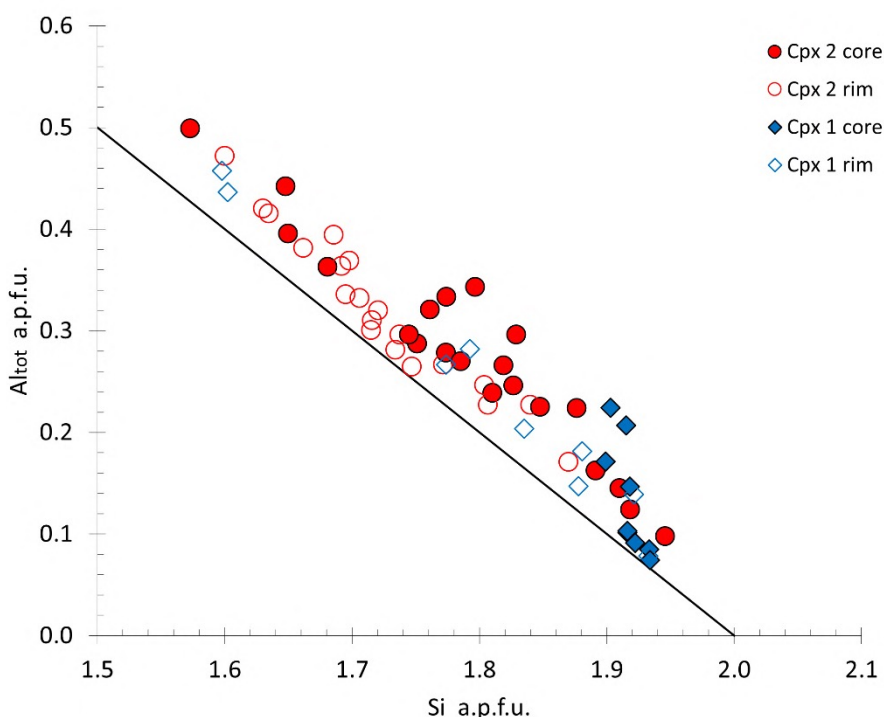


Figure 29: bivariate diagram showing the clinopyroxenes content of Si vs. Al. All analyses shown in a.p.f.u.. Solid black line represents the saturation on the tetrahedral site ($Si+Al=2$).

With respect to the Cpx DMM our samples show again two main behaviours: the mantle and most of the magmatic cores move from the Cpx DMM composition toward high concentrations in CaO, FeO and MgO.

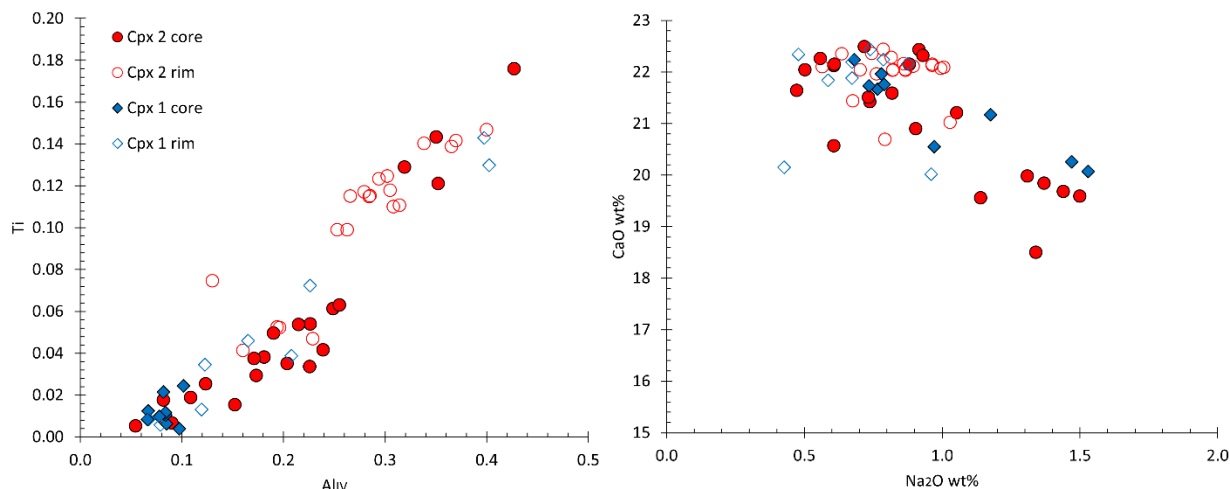


Figure 30: Bivariate diagrams showing Cpx analyses. Ti and Al^{IV} expressed as a.p.f.u.; CaO and Na₂O as wt%.

For what concerns the REE content, our orthopyroxenes show patterns mainly similar to the one of Opx calculated for the DMM, except for two samples (Fig.31), which are two spot analyses done in rims in contact with glassy patches of samples FN30 and FN38, where the glass may contribute to rising the REE content during the analyses.

It is interesting to notice that both mantle and magmatic Cpx (Fig.32) show similar patterns, similar REE contents and appear enriched with respect to the calculated Cpx from DMM. Moreover, this pattern is consistent with that of a calculated Cpx starting from the observed less evolved glass compositions (analyses FN38-5, see the following chapter) using the K_d between Cpx and trachyphonolite melt of Fedele et al. (2009).

Considering other trace elements, there is again the same feature, with our samples forming patterns that lay between the ones of Cpx DMM and OIB. With respect to the OIB, our clinopyroxenes are depleted in some LILE. Other elements are alternatively showing values similar to Cpx DMM or OIB, depending on the spot analysis. Considering all the analysed Cpx, the

majority plot over the OIB pattern in the elemental gap moving from Nd to Lu (see Fig.33). For more of these elements, this is consistent with their compatibility as shown by the K_d proposed by Fedele et al. (2009). The sole exceptions are Zr and Hf, which, showing K_d Cpx/melt of 0.32 and 0.56, respectively, should be plotted at lower concentrations.

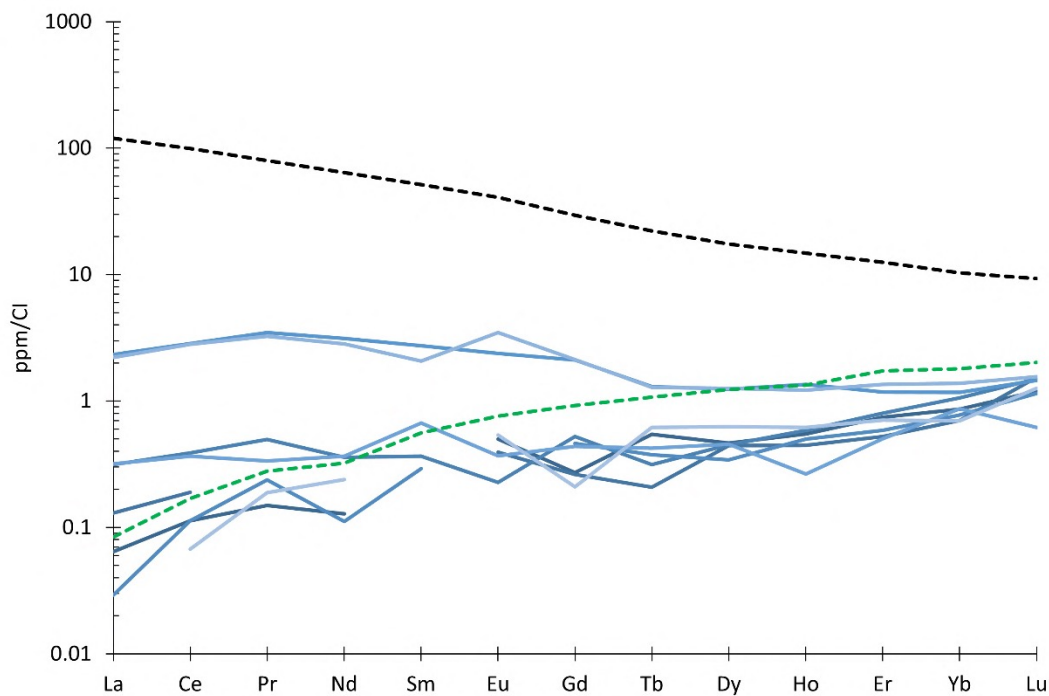


Figure 31: REE diagram for the analysed Opx. Green dotted line represent the composition of Opx DMM from Workman & Hart (2005), black dotted line the one of OIB from Sun & McDonough (1989). Data normalized to the chondrite of Boynton (1984).

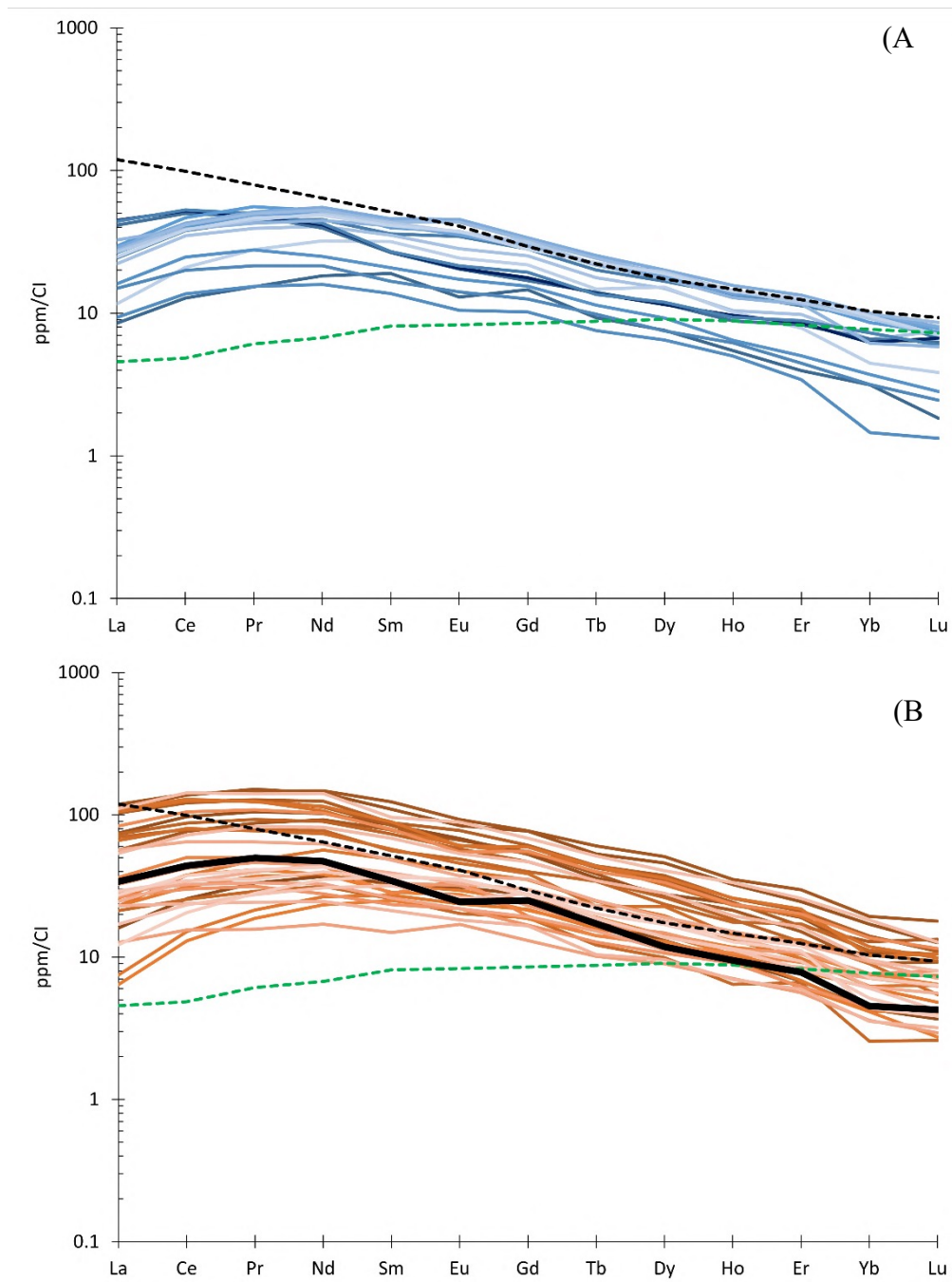


Figure 32: REE patterns for Cpx1 samples (in blue) and Cpx2 crystals (in orange). Dotted black lines represent the composition of OIB from Sun & McDonough (1989), green dotted lines composition of Cpx DMM (Workman & Hart, 2005). In B) the solid black line represent the calculated Cpx starting with our glass composition (sample FN38-5) using partition coefficients between Cpx and trachyphonolite from Fedele et al. (2009). All data normalized to chondrite values from Boynton (1984).

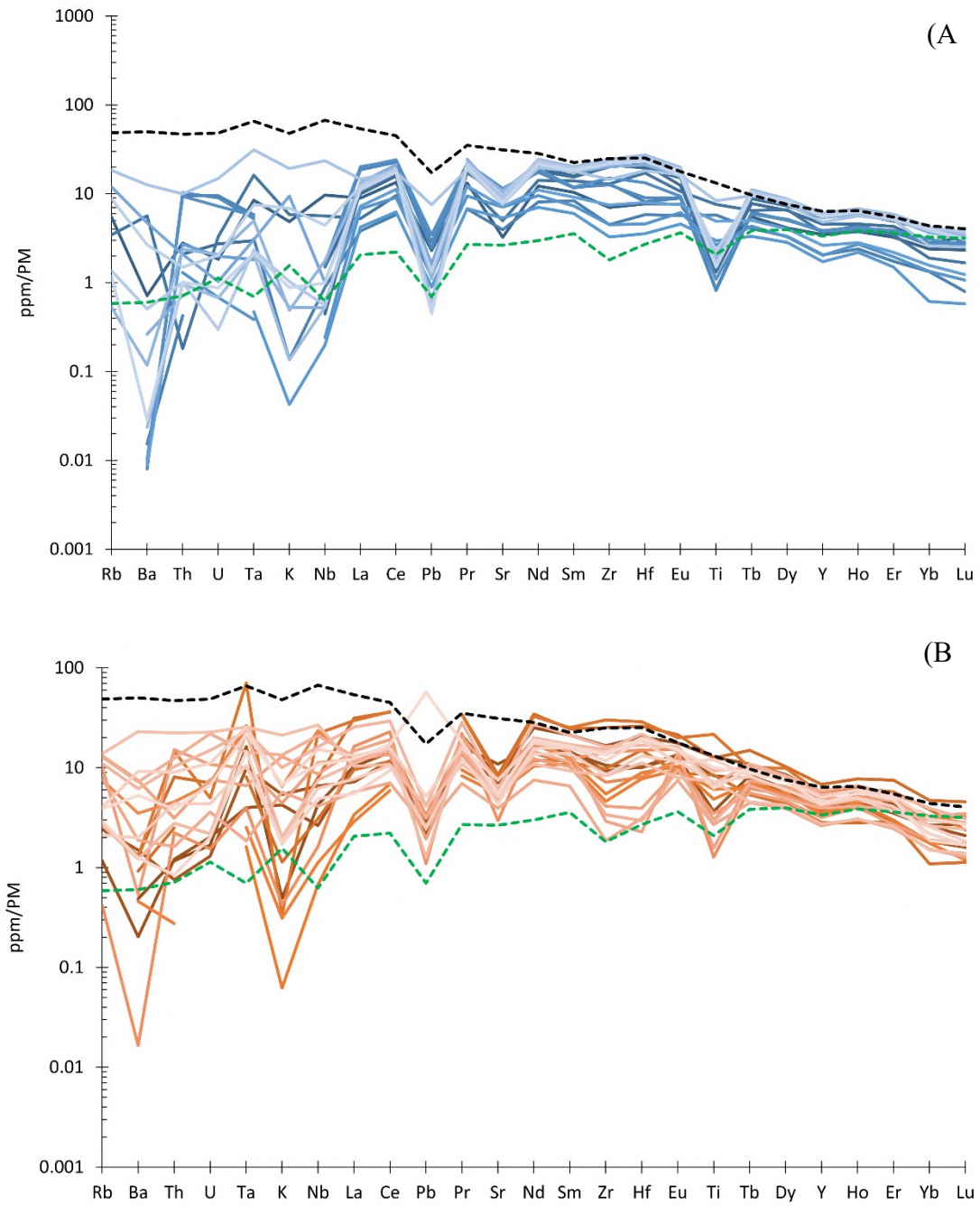


Figure 33: Spidergrams for mantle Cpx in blue and for magmatic Cpx in orange. Dotted green lines represent the composition of calculated Cpx for a DMM (Workman & Hart, 2005), dotted black lines the one of OIB from Sun & McDonough (1989). Data normalized to the PM of Sun & McDonough (1989).

Assuming that magmatic Cpx compositions were evolving along with the respective melt, we tested the geothermometer of Neave and Putirka (2017) based on the equilibrium between Cpx and melt. In Fig.34 it is possible to notice, throughout the Rhodes diagram of the model, how neither the cores or the rims of clinopyroxenes are in equilibrium with their melts, being away from the equilibrium curve plotted in green in the figure. Indeed, the model gives output pressures too high, not compatible with the presence of plagioclase ($18.6 < K_b < 29.8$, see Table4). Only two clinopyroxenes from sample FN38 and one from sample FN18 approach the equilibrium curve, giving anyway high pressures of equilibrium (20.8 and 25.3 Kb for FN38 and 26.0 Kb for sample FN18).

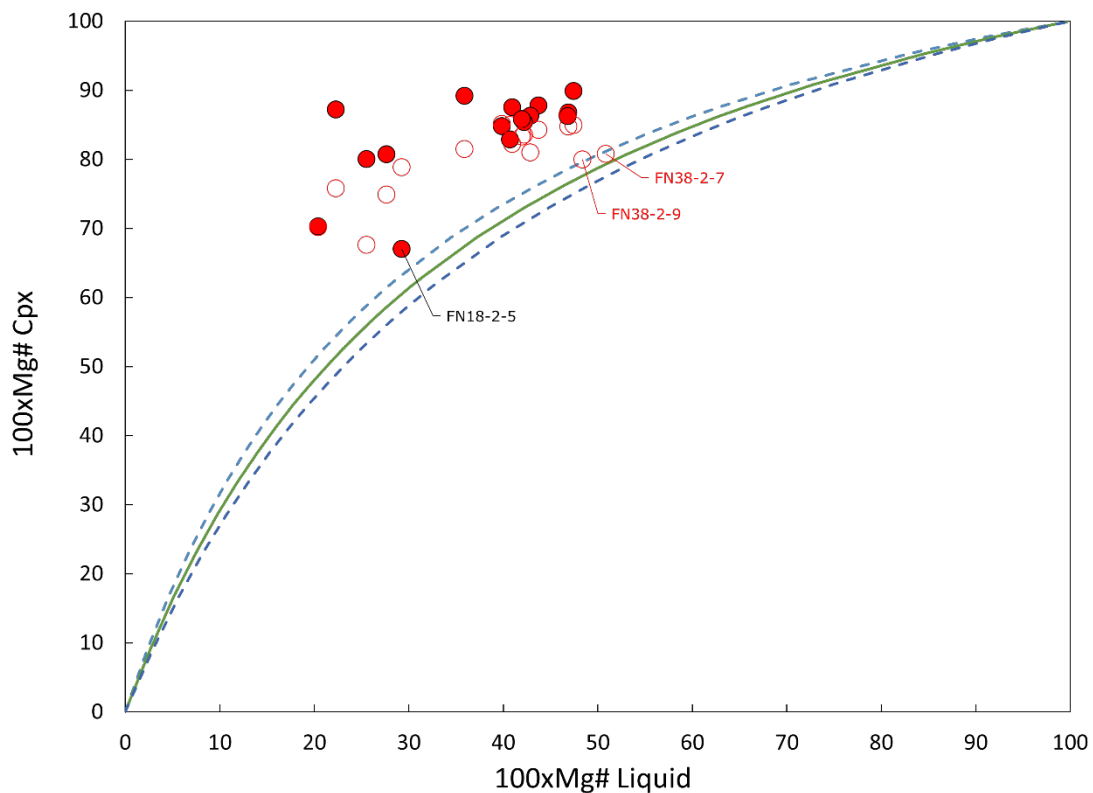


Figure 34: equilibrium diagram for Cpx and liquid from the model of Neave and Putirka (2017). Full circles core samples, empty circles rim analyses. In green the equilibrium curve with the error buffer as a dotted blue line.

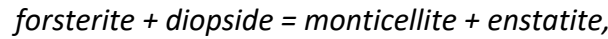
<i>Glass sample</i>	<i>Cpx sample</i>	<i>Cpx type</i>	<i>P(Kb)</i>	<i>T (°C)</i>	<i>DiHd error</i>
14-2-VTR-3	14-2-8	core	27.6	1079	0.24
30-1-VTR-1	30-1-15	core	23.6	1102	0.29
30-1-VTR-2	30-1-13	core	21.8	1096	0.28
30-3-VTR-3	30-3-7	core	23.7	1094	0.37
18-1-VTR-2	18-1-12	core	25.0	1063	0.33
18-1-VTR-3	18-1-6	core	29.8	1127	0.30
18-2-VTR-1	18-2-5	core	26.0	1068	0.48
18-2-VTR-3	18-2-11	core	28.0	1034	0.34
38-1-VTR-1	38-1-5	core	29.0	1152	0.18
38-1-VTR-2	38-1-11	core	26.4	1141	0.26
38-3-VTR-3	38-3-1	core	26.3	1120	0.05
38-4-VTR-1	38-4-17	core	22.5	1067	0.22
38-4-VTR-2	38-4-7	core	24.5	1119	0.22
38-4-VTR-3	38-4-3	core	19.7	1047	0.11
38-5-VTR-1	38-5-3	core	20.3	1042	-0.01
38-5-VTR-3	38-5-1	core	20.2	1043	-0.04
14-2-VTR-3	14-2-9	rim	23.4	1021	0.34
30-1-VTR-1	30-1-14	rim	24.4	1118	0.32
30-1-VTR-2	30-1-16	rim	18.6	1041	0.43
30-3-VTR-3	30-3-8	rim	20.9	1058	0.53
18-1-VTR-2	18-1-7	rim	27.4	1071	0.31
18-1-VTR-3	18-1-13	rim	25.8	1066	0.35
18-2-VTR-1	18-2-6	rim	27.3	1084	0.39
18-2-VTR-3	18-2-12	rim	26.8	1032	0.37
38-1-VTR-1	38-1-6	rim	22.6	1067	0.28
38-1-VTR-2	38-1-12	rim	25.1	1105	0.27
38-2-VTR-1	38-2-7	rim	20.8	1090	-0.02
38-2-VTR-3	38-2-9	rim	25.3	1123	0.26
38-3-VTR-3	38-3-2	rim	22.0	1054	0.13
38-4-VTR-1	38-4-4	rim	25.5	1086	0.18
38-4-VTR-2	38-4-8	rim	22.7	1097	0.24
38-4-VTR-3	38-4-18	rim	22.5	1062	0.05
38-5-VTR-1	38-5-2	rim	19.8	1035	-0.02
38-5-VTR-3	38-5-4	rim	19.1	1039	-0.02

Table4: P-T calculations for Cpx and respective glasses, following the model of Neave and Putirka (2017).

Temperature and pressure calculations were possible even among mantle phases, but are strongly limited by the number of analyses and the selection among them, as mantle phases that appeared as metasomatized by the melts were not suitable. The more restricting phase in that sense is orthopyroxene, which is fundamental in thermobarometric calculations, and was analysed only in samples FN30, FN38 and FN41.

To calculate the temperatures we used two different thermometers. One is from Brey & Kohler (1990), which is based on the exchange of Ca and Mg between Opx and Cpx and has a pressure dependency in the formulation. The other one is a relatively new thermometer, from Liang et al. (2012), which is based on the exchange of REE between Opx and Cpx, and is independent of the pressure.

To estimate the pressure we used the reaction:



and two sets of thermodynamic models. One is the empirical geobarometer of Kohler & Brey (1990), which suggests two equations depending on the temperature of equilibration:

$$P = (-T \cdot \ln D_{Ca} - 11982 + 3.61 \cdot T)/56.2 \quad (1)$$

$$P = (-T \cdot \ln D_{Ca} - 5792 - 1.25 \cdot T)/42.5 \quad (2)$$

The other model is based on the end-member thermodynamic data of Holland & Powell (2011) and has been applied using the software Thermocalc (Powell & Holland, 1988, 1994; <https://hpxeosandthermocalc.org/>) and the set of solution models suggested by Holland et al. (2018). Outputs of all the calculations are given in Table5, with sample FN41 showing the best results in terms of standard deviations and consistency among different calculations.

Sample	Phases	Used spots	T°C (Brey&Kohler)	T°C (REE)		P (Kb) Kohler&Brey		P (Kb) Thermocalc	
				<i>s.d.</i>		<i>T°C</i> (B&K)	<i>T°C</i> (REE)	<i>T°C</i> (B&K)	<i>T°C</i> (REE)
FN30	Ol	30-3-9	1106	878	138	11.23	-13.20	17.18	-
FN30	Opx	30-1-20							
FN30	Cpx	30-1-13							
FN38	Ol	38-6-6	913	974	128	-3.31	7.42	2.76	12.17
FN38	Opx	38-6-4							
FN38	Cpx	38-6-1							
FN41	Ol	41-2-10	996	1006	32	4.44	6.19	5.62	7.22
FN41	Opx	41-2-1							
FN41	Cpx	41-2-14							

Table 5: geothermobarometric calculation outputs based on mantle phases on samples FN30, FN38, FN41. The used spot analyses in calculations are also reported. See text for details.

6.4 Plagioclase

As stated in the petrographic section of this work, all plagioclase crystals are magmatic in origin and are located inside glassy patches. As shown by the classification diagram in Fig.35, they have a narrow range in the percentages of anorthite and albite, being in the fields of labradorite to andesine. This indicates they fractionate from a residual melt variably evolved.

In two plagioclases, which are sufficiently large in dimensions, one from sample FN18 and one from xenolith FN38, we performed traverses from core to rim. The concentrations of some elements are shown in Fig.36. As visible by the decreasing CaO content and increasing Na₂O from core to rim, the direct zonation observed in the thin sections is confirmed.

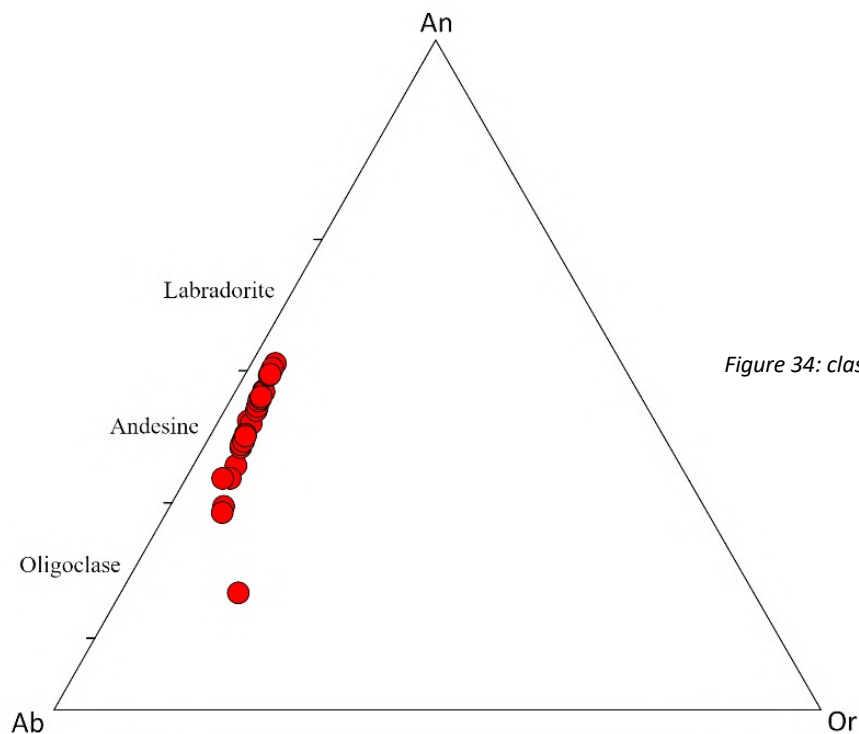


Figure 34: classification ternary diagram for feldspars.

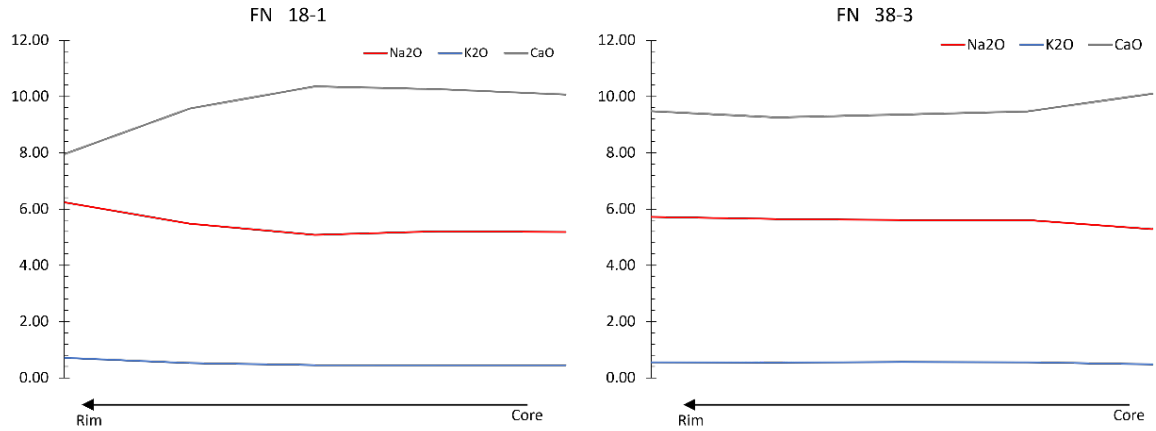


Figure 35: two traverses made on plagioclase crystals. Oxides contents expressed in wt%.

We calculated temperatures for plagioclases with the model of Putirka (2008). Considering the presence of plagioclase and geobarometric calculations that give pressures in the range of 2.76 Kb to 17.18 Kb, we used in the model a range of 3 to 10Kb, resulting in temperatures between 1040°C and 1290°C. In Table6 we reported temperatures for an assumed pressure of 5Kb.

<i>Sample</i>	<i>P (GPa)</i>	<i>Mean T (°C)</i>	<i>dSt</i>	<i>dSt.c</i>	<i>dSt.p</i>
41-2-12	0.5	1254	61.3	61.3	50.1
41-2-13	0.5	1261	55.6	55.6	45.4
41-3-1	0.5	1050	84.9	84.9	69.3
41-3-2	0.5	1052	83.4	83.4	68.1
30-1-7	0.5	1096	90.1	90.1	73.6
30-1-8	0.5	1089	95.9	95.9	78.3
30-1-9	0.5	1095	91.3	91.3	74.5
30-1-10	0.5	1089	96.2	96.2	78.5
30-3-1	0.5	1104	88.4	88.4	72.2
30-3-2	0.5	1100	91.2	91.2	74.4
30-3-3	0.5	1107	85.6	85.6	69.9
30-3-4	0.5	1107	85.4	85.4	69.7
18-2-1	0.5	1099	104.8	104.8	85.6
18-2-2	0.5	1094	108.7	108.7	88.7
18-2-3	0.5	1094	108.8	108.8	88.8
18-2-4	0.5	1094	108.4	108.4	88.5
38-1-9	0.5	1128	96.0	96.0	78.4
38-1-10	0.5	1127	96.6	96.6	78.8

Table 6: temperatures calculated for a pressure of 5Kb with the model of Putirka (2008).

6.5 Amphibole and Apatite

As reported in the petrography section, we found several occurrences of apatite (analyses attached in AppendixG) and few amphibole. One crystal is sufficiently large in dimensions to be analysed (see Fig.8A) and gives the composition of tschermakite as visible in Fig.36.

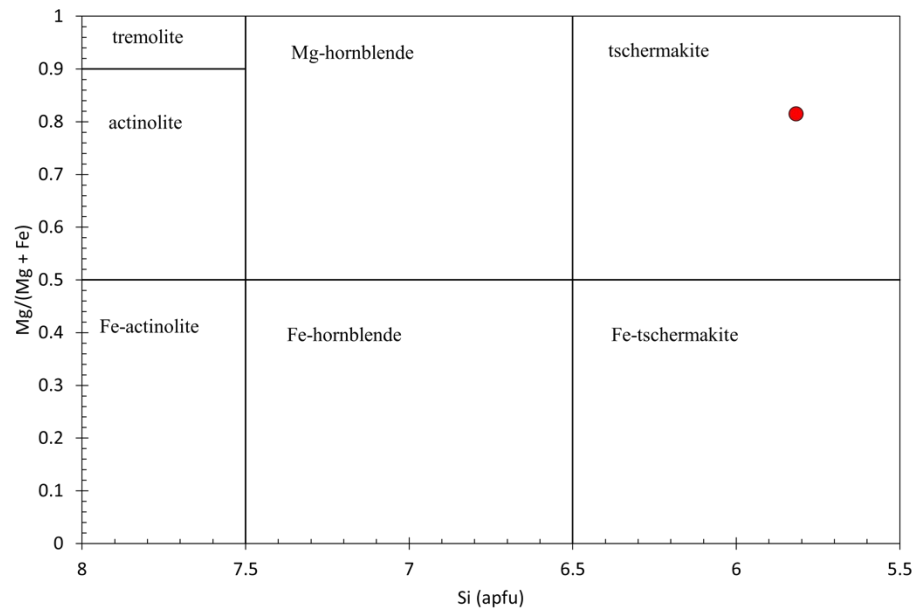


Figure 36: classification diagram of amphibole, after Leake et al. (1997)

Applying the geothermobarometer of Putirka (2016) based on the equilibrium between amphibole and liquid, we obtained a temperature of 1039°C and a pressure of 5.5Kb.

7. Glass

We analysed 38 spots on 12 different glassy patches inside all of the five mantle xenoliths selected. The SiO_2 content ranges between 50.49 wt% and 59.93 wt% while MgO is detected with values in the range $0.01 < \text{MgO} < 2.26$ wt%. What is noteworthy is their content in alkali, as Na_2O goes from 1.94 wt% to 8.84 wt% and potassium is in the range $0.99 < \text{K}_2\text{O} < 11.99$ wt%. As visible in the TAS diagram of Fig.37, samples are well above the alkaline-subalkaline boundary of Myashiro (1978). Analyses from sample FN38 display the wider range in composition, although being all in the tephri-phonolite/phonolite fields; however, it has to be considered that this is the sample in which glasses were more scattered, forming both large patches and small pockets, thus may be experienced a different evolution due to local different fractionations or different case of OPX assimilation (see later). Sample FN41 show two different behaviours, with two spots following all the other glasses, being trachytic-phonolitic in composition (following the TAS diagram fields), while three others are in the trachy-andesite field. Notably, in the tomographic chapter, we testified that the glass completely permeates the xenolith. Given the petrographic observations, it has to be considered that this is the sample with the lower amount of glass and the clearer clues of orthopyroxene partial assimilation, thus analyses may be influenced by the chemistry of partially melted phases or by the presence of zeolites contaminating the spot analysis. Moreover, as underlined in the geology chapter of this work, samples may be altered in their sodium content by alteration due to seawater. In addition, considering they are the only glass analyses which sum close near to 100 wt% (thus having a low volatile content) analyses may be contaminated by the presence of plagioclase. For all these reasons, considerations about sample FN41 have to be made carefully. Considering the alkali alone, in the diagram of Fig.38, it is possible to see how samples are all potassic, with the exception of the analyses of sample FN41 that were already highlighted as questionable in the TAS diagram. Here is more evident how they show an anomalous content in Na_2O with respect to other glassy patches, thus supporting the possibility that analyses were contaminated by the presence of zeolites and/or seawater alteration of the sample. It is worth noticing that the hosting basanites are in the sodic field, suggesting they have a different source with respect to the melts that formed the glassy patches.

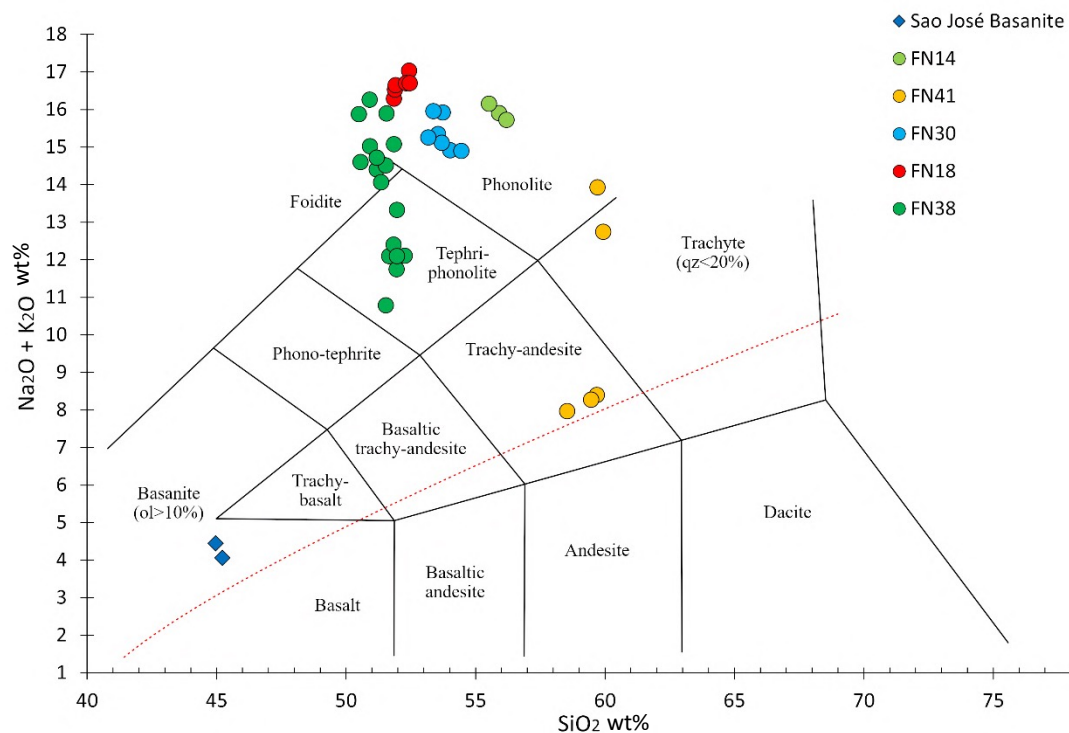


Figure 37: TAS diagram from Le Bas et al. (1986), full circles showing the composition of our glasses analyses, as indicated in the legend. Red dotted line represents the boundary between the alkaline and subalkaline fields from Myashiro (1978).

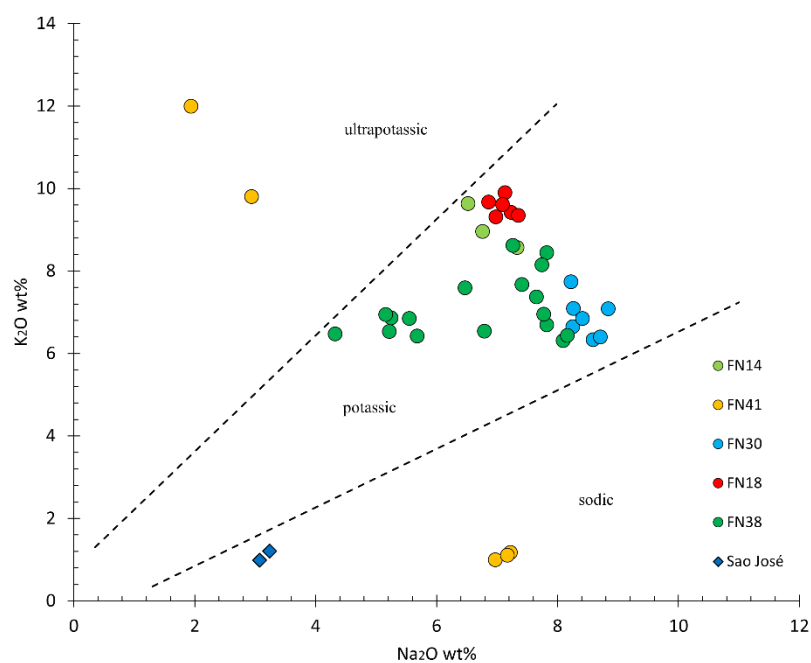


Figure 38: discrimination diagram for sodic, potassic and ultrapotassic magmas. Field from Middlemost (1975).

Another interesting thing to be considered is that samples showing the narrow compositional ranges between different spot analyses are FN18 and FN30, which are the two with the best glassy patches for extent, absence of microlites, scarcity of zeolites and homogeneous colour under polarized light. Among the more potassic samples, there are glasses from xenolith FN14, which is the only one showing the presence of amphibole crystals inside glassy patches in thin section.

Considering MgO as an evolutionary index, samples show, as expected, no evidence of an evolution characterized by fractional crystallization. Rather suggesting the presence in all the studied xenoliths of a potassic to high-potassic melt, with only slight differences between different samples or separate glassy patches. Looking at the De La Roches diagram of Fig.40, it is worth noticing that all the glasses are strongly evolved and alkaline in nature and notably show a wide range of values in R1 while they are in a narrow range of R2. Moreover, the diagram shows how glasses appear more evolved in comparison with the main lithologies forming the FN archipelago, with the only exception of aphyric phonolite from the Remédios sodic series.

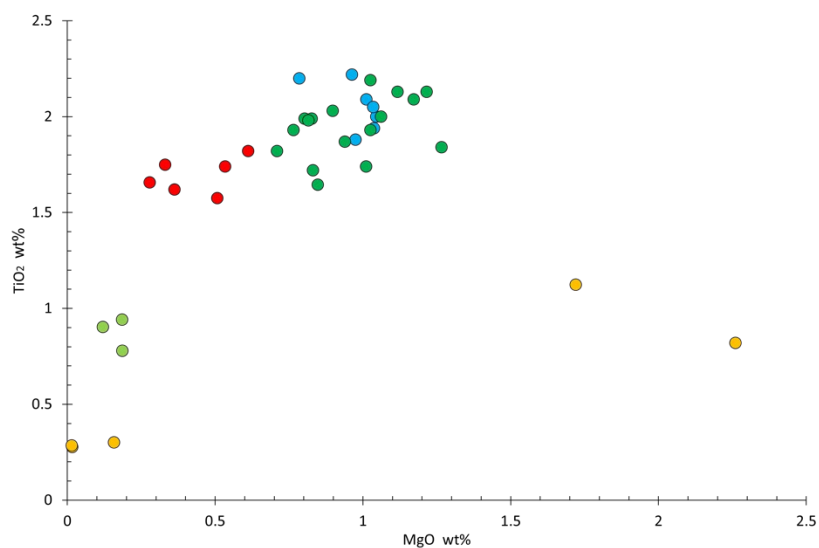
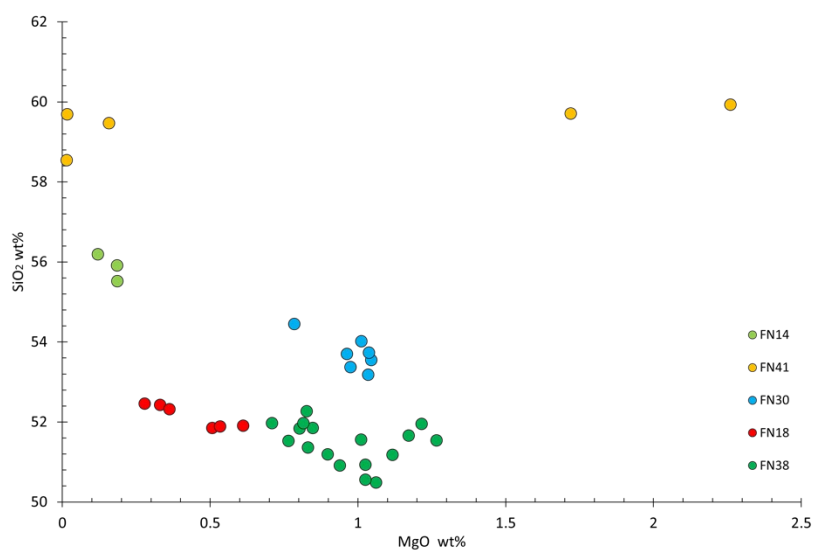
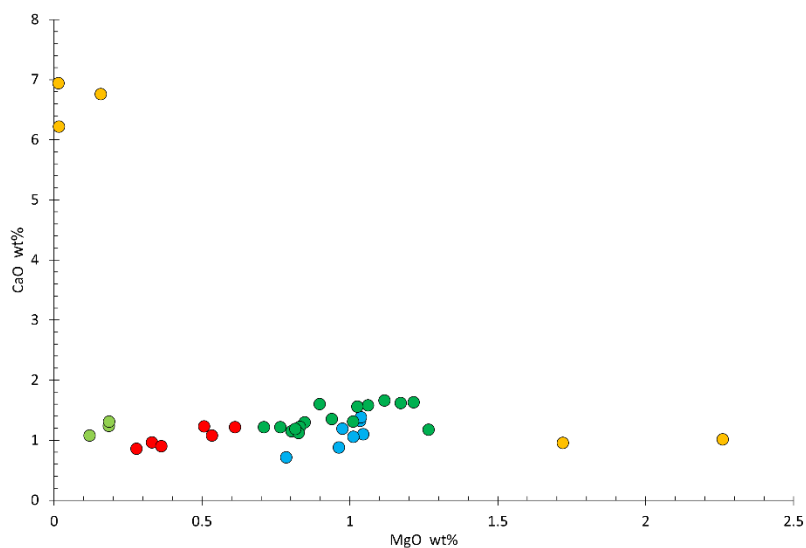


Figure 39: bivariate diagrams showing the content of some major elements with respect to the MgO, used as an evolutionary index. All data expressed as oxide wt%. Symbols as in Fig.38.

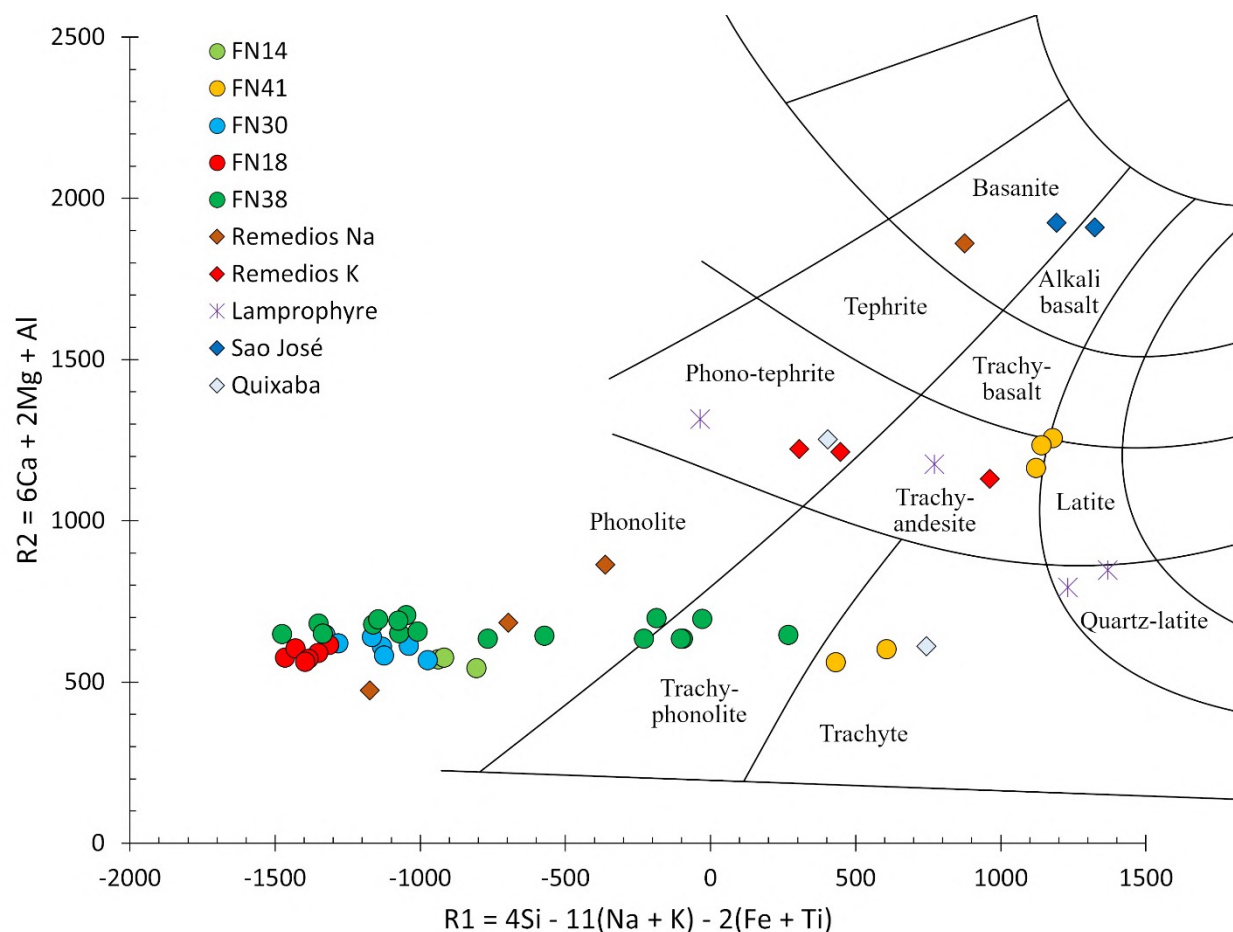


Figure 40: De La Roches diagram (1980) showing values of R1 and R2 in our samples and in the hosting basanites of Sao José. FN rocks analyses from Lopes & Ulbrich (2015).

REE patterns of our glasses (Fig.41) are quite similar to each other, except for three glasses from sample FN41 (in the trachyandesite field), not shown in all the following figures but attached in AppendixN. They are all enriched, particularly with respect to the DMM and in comparison to an OIB, they show a similar HREE slope (mean $Er/Yb=1.3$ vs. 1.2) but are enriched in LREE (mean $La/Nd=1.67$ vs. 0.96). The Eu/Eu^* is quite variable, showing negative, flat or positive spikes.

Interestingly, compared to the main formations of the island (Fig42A), they differ from the Sao José basanites, the lamprophyre and the Na-Remedios formation, which are similar among them showing a different slope both in L- and HREE. Instead, our glasses show similitudes with the K-Remedios formation which is represented by quite evolved rock types. Considering the melt in equilibrium with the Cpx that shows the less enriched REE pattern (Cpx1 spot analyses 18-2-16

in AppendixL), calculated through partition coefficients between Cpx and Trachyphonolites of Fedele et al. (2009), it appears like a parental melt both of the studied glasses and the K-Remedios rock types.

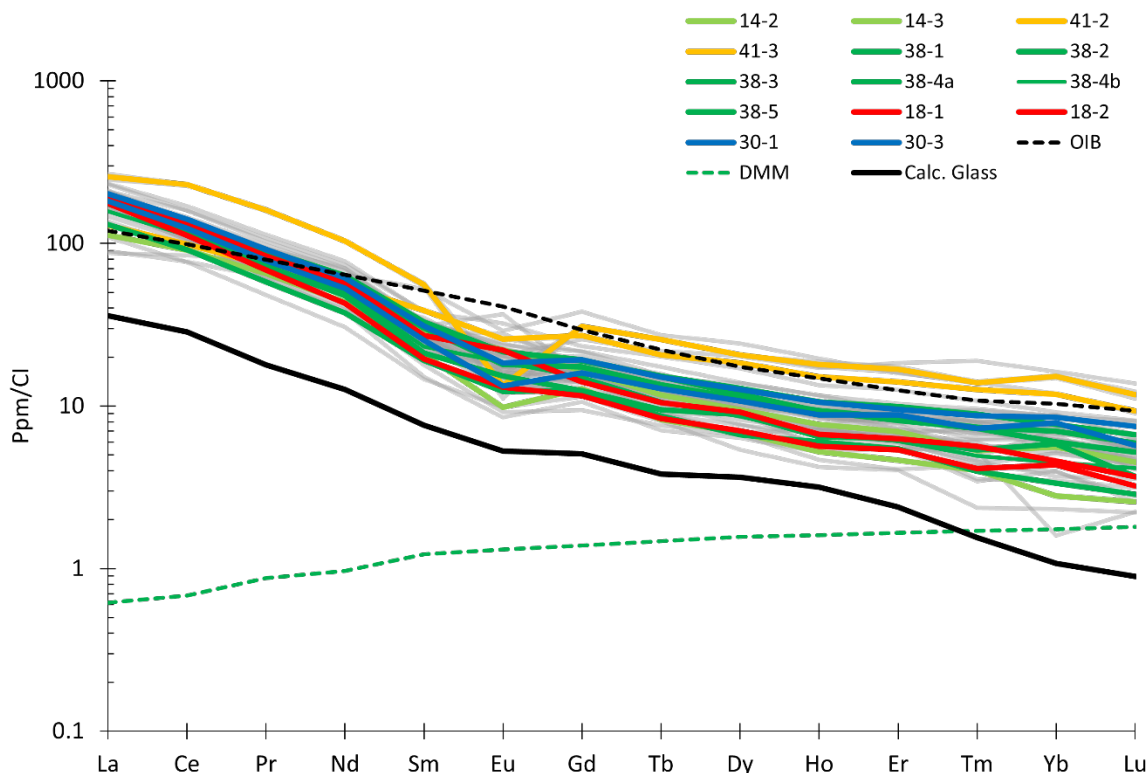


Figure 41: REE patterns of all the spot analyses on glasses in light grey. Coloured patterns are the mean values calculated on analyses regarding the same glassy patch. As green dotted line the DMM composition from Workman & Hart (2005), black dotted line the OIB pattern from Sun & McDonough (1989). Solid black line the calculated glass composition from Cpx REE using partition coefficients of Fedele et al. (2009). Data normalized to the chondrite of Boynton (1984).

Considering other trace elements, glasses show enrichment in LILE with respect to an OIB pattern (Fig.43) and are strongly enriched in all elements with respect to a DMM. Sample FN30 shows low concentrations of Ba and Sr with respect to the other glasses. In general, all samples show positive anomalies in Nb, Zr and Hf. Ti and Pb may be slightly positive or negative in the respective spikes or, alternatively, are flat. The most important differences regard Ba, Sr and Eu which are mainly characterized by variable negative spikes due to the plagioclase fractionation. All the analyzed glasses show a good affinity with the K-Remedios pattern, with the only exception of Ti. This last element is characterized by a slight negative anomaly in Rémedios, probably due to opaque fractionation, that is not observed in the studied glasses.

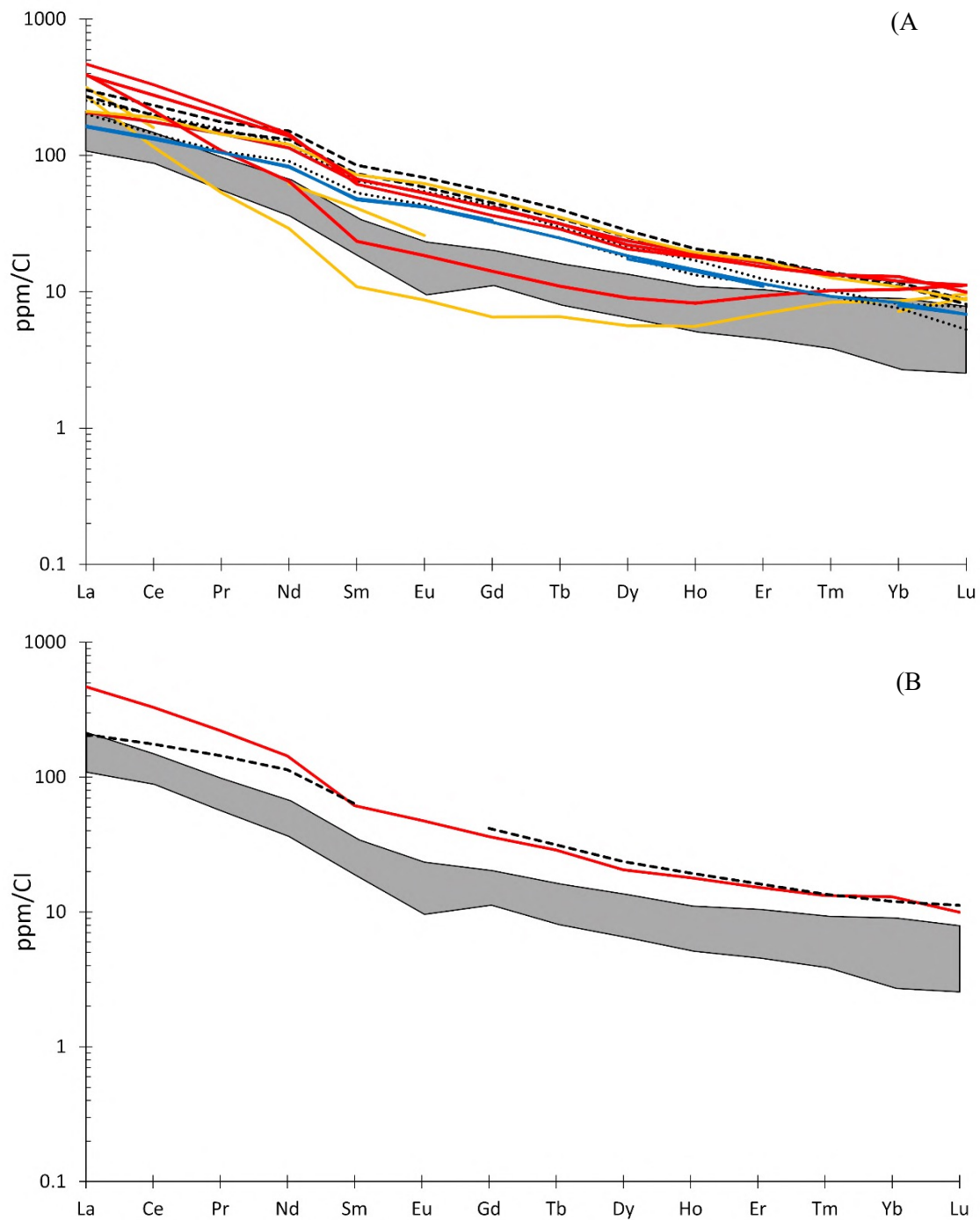


Figure 42: The REE pattern of all our glasses, excluding sample FN41, is represented as grey field. A) Main formations from FN archipelago, in red lines Rémedios K-series, in yellow Rémedios Na-series, as black dotted lines lamprophyres and melanephelinites and in blue the São José basanites; data from Lopes & Ulbrich (2015); B) Our glasses (grey field) compared to the trachyandesite (red solid line, sample P7FN3C; Lopes & Ulbrich, 2015) and the alkali basalt (black dotted line, sample 97FN35b; Lopes & Ulbrich, 2015) from Rémedios K-formation.

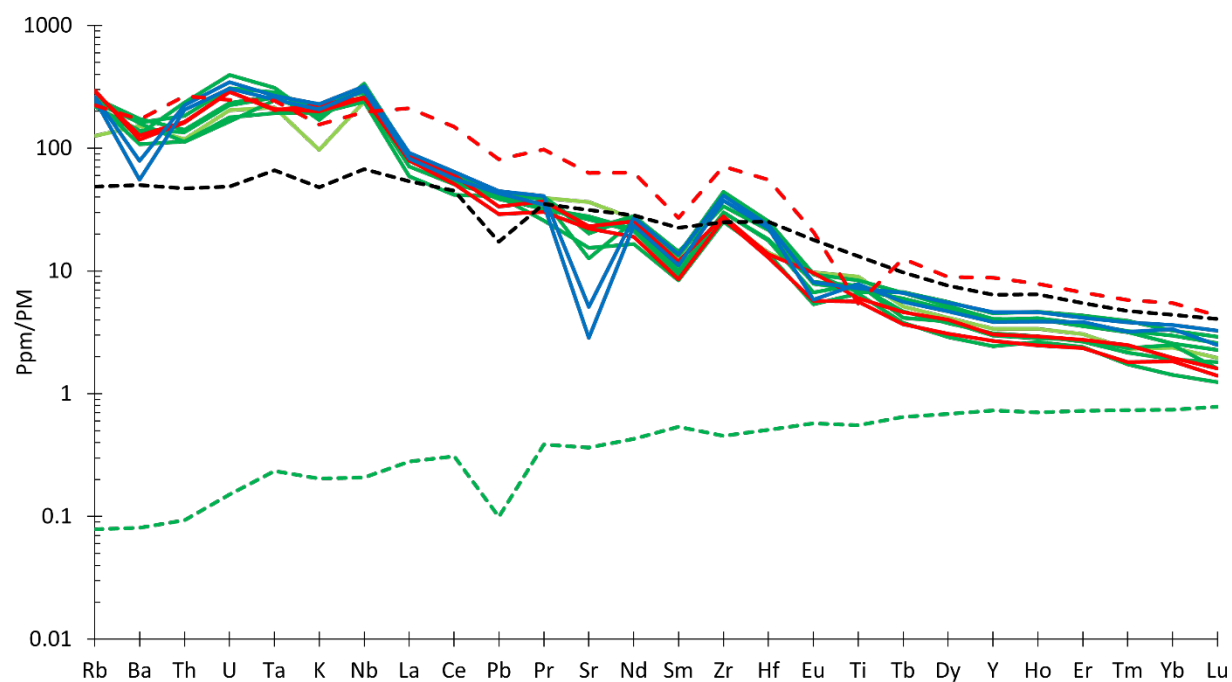


Figure 43: spidergram of some trace elements on our glasses, excluded sample FN41. Colours as in Fig.41. Green dotted line for DMM composition of Workman & Hart (2005) and dotted black line for the OIB of Sun & McDonough (1989). As red dotted line the analyses of the trachyandesite from Rémedios (Lopes & Ulbrich, 2015). Data normalized to the PM of Sun & McDonough (1989).

8. Discussions

8.1 Textural considerations

The results of petrographic characterization show that only few of the forty-eight samples of mantle xenoliths coming from the Sao José formation present strong evidence of interactions between peridotite and the host basalts. Although this evidence, these xenoliths clearly represent different situations with respect to the five occurrences we selected for this study. One example is sample FN34, in Fig.44, showing the infiltration of the host basanite in the xenolith. In this sample, we can see that basanite follows a fracture showing no reaction with the nearby phases and has little to no effect on the peridotite.

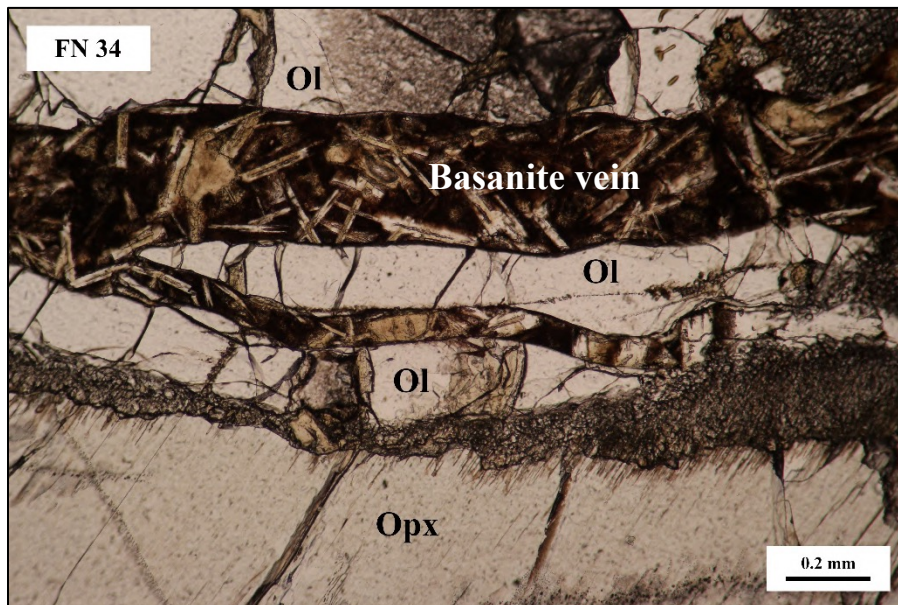


Figure 44: thin section of sample FN34 showing a fracture filled by a vein of the hosting basanite. Ol = olivine; Opx = orthopyroxene.

As stated in the petrographic section of the results, the glassy patches in the selected samples show instead clear interactions between the melt and the host peridotite. The two firmer pieces of evidence of this interaction are the presence of several magmatic crystals growth at the boundary of the mantle phases (as in Ol of Fig.7 or Cpx in Fig.8B), and reaction coronae in mantle minerals that are surrounded by the glass (see the Opx in Fig.8C). The reaction between strong alkaline magmas with orthopyroxene (saturated silica phase) could suggest an increase of silica in the melt, with consequent disequilibrium between the observed glass and the fractionated

phases (see later in the text). All our glassy patches show evidence of fractionation, which means we are looking at a residual melt. Among the crystallized phases, olivine and clinopyroxene are always abundant and plagioclase is variably present. The sporadic presence of hornblende in the glasses of sample FN14 suggests a generally $P_{H_2O} \gg P_{tot}$. In that regard, in several glassy patches evidence of degassing is observed, expressed by bubbles that now are fulfilled by zeolites, this implies melts were rich in volatile phases. Another textural evidence of a low depth is the fractionation of plagioclase in the patches, testifying that melts were (at some point) at least below 10 Kb.

Moreover, petrography shows evidence of possible disequilibrium between the melt and the phases that fractionate, as clinopyroxenes in particular show rims different in compositions with respect to the cores (see Cpx2 in Fig.45). This may be due to evolution in the melt composition because of both fractionation or assimilation, or by changes in the composition of the magmatic phases because of changings in the pressure of crystallization during the ascent of mantle xenoliths. Among all these pressure-related questions, there is even the presence of both Cr-spinel and plagioclase inside the glassy patches. Petrography shows that plagioclase is clearly one of the last phases to be formed, as it is impossible to find it as inclusion in other minerals and usually grows in contact with Cpx or Ol using them as a base for crystallization and occupying the remaining space in the melt as in a hypidiomorphic texture (See Fig.45). Cr-spinel, in contrast, is one of the first phases to crystallize, as it is often present as inclusion in both olivine and clinopyroxene. At the same time, spinel shows in some occurrences a skeletal texture testifying a high cooling rate. This testifies that melts fractionated during spinel-plagioclase phase transition, in a gap of pressures between the lower limit of the spinel stability field (about 12.5 Kb; Borghini et al., 2010) and the higher of plagioclase (10Kb; Borghini et al., 2010) and this attests a relatively fast uplift of 2-3 Kb before the eruption of the basanite (the melt inside do not show any affinity with the hosting basanite).

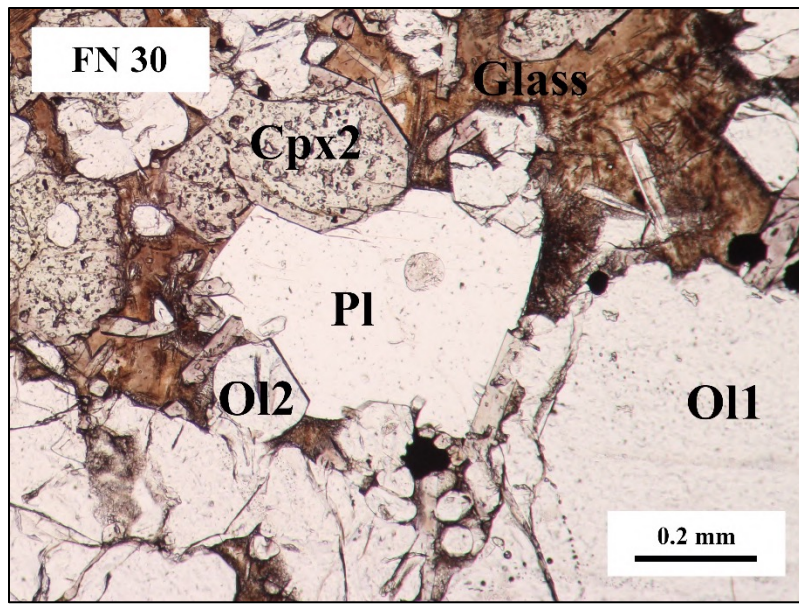


Figure 45: thin section of sample Fn30 showing a glassy patch with plagioclase (Pl) mantle and magmatic olivines (Ol1 and Ol2 respectively) and magmatic Cpx (Cpx2).

Considering glass, the main question about microscopic observations was: is it isolated, representing melt generated by melting of phases composing the xenolith, or are there connections between glassy patches? To find an answer to this and many other questions it is not sufficient to look at the texture in conventional 2D sections. The answer is given by the application of 3D X-ray microtomography to our samples. Throughout a skeleton analysis, we studied, for every sample imaged, the connectivity density of the glass. As visible in Tab.3 and Fig.46, glasses are highly connected among them, and this is visible from the first lower resolutions. Moreover, they are not channeled in some specific areas of samples but are randomly scattered in all the xenoliths. This shows that these melts are not the result of partial melting due to the exhumation of deeper-seated xenoliths, but they are percolating the captured xenoliths. Melts take advantage of every space, even the interstitial ones, as visible in high-resolution analyses made with the synchrotron light X-ray source. This is fundamental information, since it shows that most crystals inside the xenolith, and not only the phases in contact with the larger patches (as the only observation of 2D sections may suggest) may be reached by the melt, and react with it.

The multiscale approach we used (see the appended manuscript in AppendixA), turned out to be the best to analyze both a significant volume of sample on one hand and to study the small-scale details at the same time. Spinel, for example, is clearly visible at a lower resolution only in its larger occurrences, as reported in the results section. Despite this, its presence is underestimated without a high-resolution analysis. Working in sub-volumes of the same samples for every step of incremental resolution allows avoiding misinterpretation in the textural analyses, as testified in Fig.47.

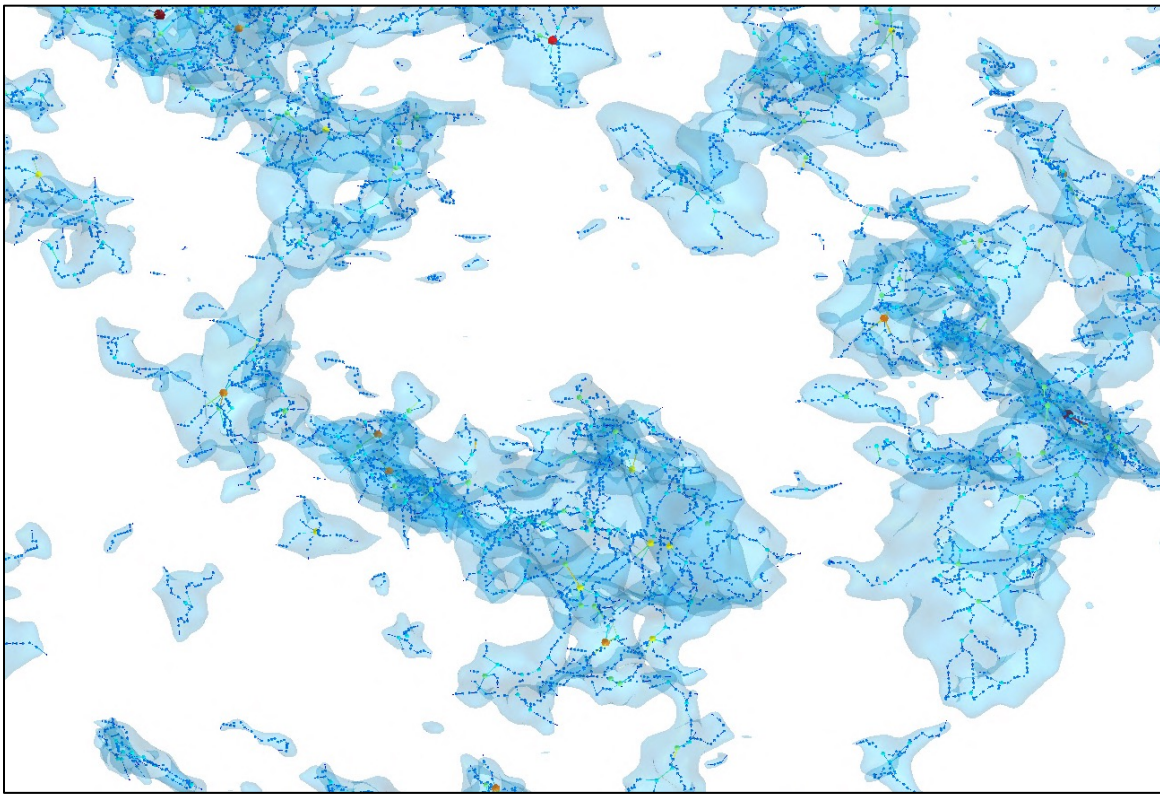


Figure 46: image was taken on sample FN38, step B of the micro-CT analyses. In faded blue the segmented volumes of glass. Inside the volume is possible to notice the skeleton analysis, with lines as edges and spheres as vertices. Vertices are coloured with the colour spectrum based on their connectivity values, the higher the connectivity, the higher the wavelength of the colour. (Consider that low levels of connectivity means a more percolating melt, as their vertices are connected just one to the other)

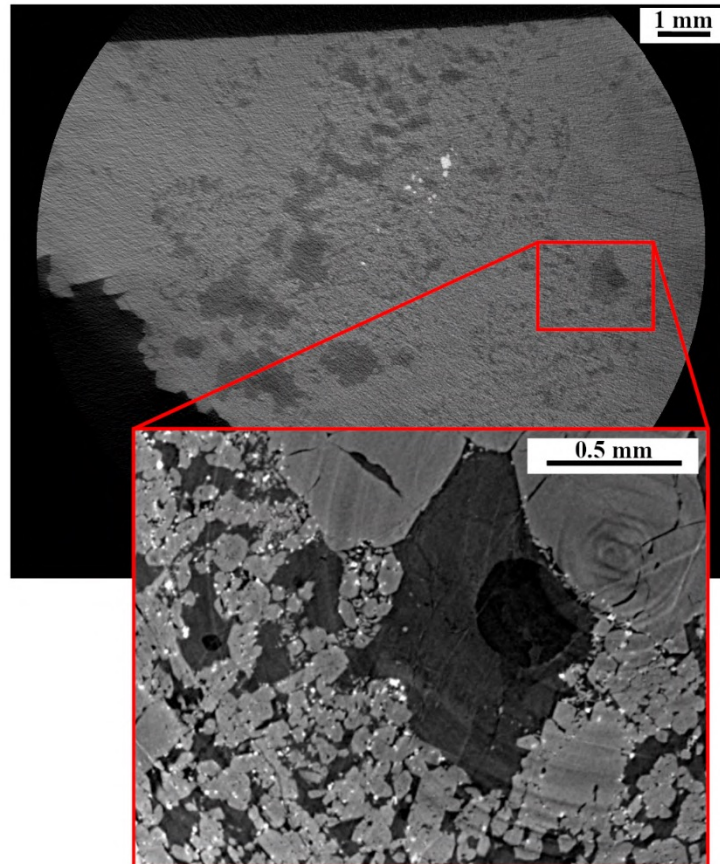


Figure 47: two slices extracted from the processing of sample FN38. At the top of the figure the sample taken during step B, with a voxel size of $6.7\ \mu\text{m}$. At the bottom a slice from step C, at $2.5\ \mu\text{m}$ of pixel size. Notice the smaller spinels (high absorption material, in white) are visible at high resolution but not at the lower one.

Moreover, the high-resolution acquisition performed with synchrotron light radiation allows us to characterize spinel textures not visible with conventional optical microscopy. Three different situations emerged for the magmatic spinel fractionated inside glassy patches:

- well crystallized in fully octahedral shape (sample FN14),

- octahedrons with skeletal-like texture (samples FN18 and FN30) and small, strongly disseminated,
- sub-rounded crystals ($1 \cdot 10^{-2}$ mm as average diameter, in samples FN38 and FN41).

The first one testifies optimal conditions for spinel crystallization. The second one is indicative of a fast cooling that favors the growth of edges with respect to crystal faces. The latter may represent the first stages of nucleation for spinel, which did not have time to develop larger crystals. Alternatively, they may represent fragments of original spinel trapped inside the melt. Interestingly, the sample with the larger, well-formed octahedral magmatic spinel is FN14, which is the only one not showing plagioclases in its glassy patches.

8.2 Mineral chemistry

Considering the mantle phases, their chemistry shows the presence, underneath the archipelago, of a mantle enriched with respect to the average DMM composition, which is the one expected in an oceanic domain. For spinels, there is not even an appreciable difference between the composition of mantle crystals and the one formed inside the glassy patches. They are quite similar and show two main compositional trends, as visible in Fig.19. The main trend is a mixture between the Rum and the Cr-Al trends of Barnes and Roeder (2001), where the latter is due to spinels exchanging with olivine at a constant temperature and is typical of mantle xenoliths from various geodynamic settings. The Rum trend is more unusual and is thought to be caused by the interaction between cumulus chromite, its intercumulus liquid, and plagioclase and olivine crystals. This trend is usually restricted to mafic layered intrusions. Nevertheless, a group of magmatic spinels show a clear Fe-Ti trend, with increasing Fe^{3+} , Fe^{2+} and Ti. That trend is attributed to the normal evolution of spinel composition during fractionation of olivine and clinopyroxene in basalts or in mafic-ultramafic igneous bodies. Interestingly, only few samples plot inside the field of spinel from ocean-floor peridotites (the one expected in this geodynamic context), while the majority are inside the field of spinel from continental mantle xenoliths. Moreover, REE content of spinels shows a concentration of La directly proportional to Ce (see Fig.21B), with all the analyses showing an overall R^2 value of 0.99, proving that, despite being in

different xenoliths, they all derive from the same source. This is true even for the spinel of sample FN30, showing in the pattern of Fig.21A that concentrations of both La and Ce are compatible with the Sp DMM.

Olivines show systematic differences between mantle phases and magmatic ones, but only for what concerns cores. Indeed, cores of mantle phases have a DMM-like composition, the respective rims on the contrary show various degrees of chemical exchange with the glasses, having compositions similar to magmatic olivine crystals. At the same time, we have some samples of magmatic occurrences showing major elements composition similar to the ones of Ol DMM. This is confirmed even by trace elements analyses as visible in Fig.24B and 25B, which means some crystals inside glassy patches are porphyroclasts of mantle olivines. They are re-equilibrating with the chemistry of the glass, developing an overgrowth of euhedral habitus. The amount of these re-equilibrated olivine clasts is difficult to be estimated. Moreover, re-equilibration appears to be faster for major elements instead of trace elements, as there are few major element analyses of magmatic crystals nearby the Ol DMM composition (two analyses, see Fig.22), while there are several analyses among REE and trace element patterns of magmatic olivines with a flat composition like the mantle phases.

Among major elements, the one that seems to better discriminate between truly magmatic olivines and mantle ones (both genuine and metasomatized) is Ca, as visible in Fig.48. Magmatic Ol have an increasing CaO content at decreasing Fo values, which identifies a trend like olivines from mantle xenoliths of Wau-en-Namus, which have experienced percolation by metasomatic melts as reported in the literature (Miller et al., 2012; Narduzzi, 2012, unpublished data). The only exception is visible for mantle olivines of sample FN18 that show low values of Fo in cores analyses ($79.5 < \text{Fo} < 81.3$) with a CaO wt% lower than 0.2 but having rims analyses with the same Fo values at higher CaO contents, plotting along with the trend described above.

Moreover, it must be noted that the majority of mantle olivines have Fo values lower than the Ol DMM, while very few samples have a composition more depleted, with Fo higher than 89%.

Summarizing, for our analysed Ol crystals, we have four different occurrences:

- pristine mantle olivines that experienced, in the majority of the occurrences, enrichment due to exchange with the percolating of melts;
- rims of mantle crystals that reacted with the melt, showing a composition similar to magmatic Ol;
- mantle xenocrysts surrounded by glass that show various degrees of re-equilibration with the melt, which may include the overgrowth of euhedral magmatic olivine;
- magmatic crystals fractionated directly from the melt.

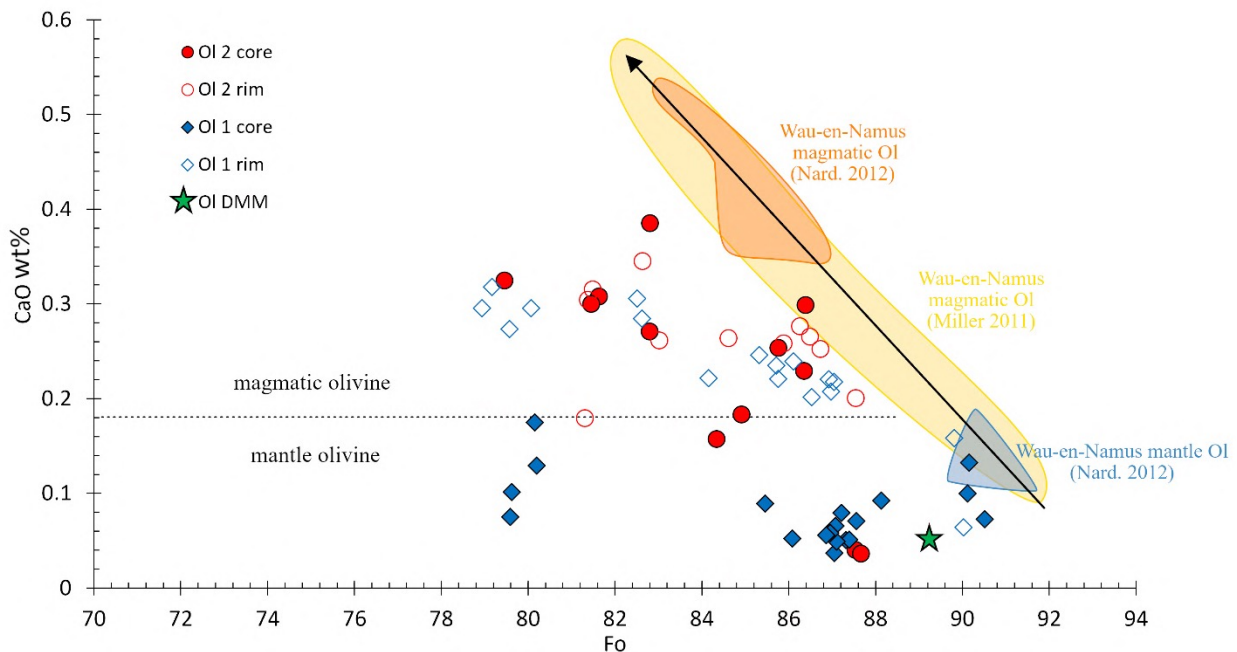


Figure 48: bivariate diagram showing forsterite content in our samples with respect to CaO wt%. Fields are from olivine compositions in mantle xenoliths from Wau-en-Namus, Libya. Data from Miller et al. (2012) and Narduzzi (2012, unpublished data). Black arrow highlighting the magmatic trend. Black dotted line represents the possible boundary between the mantle and magmatic phase compositions.

Orthopyroxenes are quite similar among them and show a composition that is poorly to no influenced by the presence of the melts. Even their trace element content is quite similar to the Opx DMM, with the only exception of two rim analyses. Olivines on the contrary, despite having a low affinity with most of the trace elements exactly as Opx, are far more enriched. This is one more evidence of the ease of olivine to recrystallize and re-equilibrate in presence of melts.

However, as petrographic evidence underlined, orthopyroxenes play a fundamental role in the composition of our glasses reacting with them.

Clinopyroxene from mantle xenolith, such as mantle olivine rims, are similar in composition to those from the fractionated melts. In particular, this is observable in all the olivine rims and in most clinopyroxenes (core and rim) and is particularly clear in the REE and EI patterns.

Considering the already discussed strongly diffusion of the melts, which permeated even intergranular spaces, we suggest that this could be due to the strong metasomatic imprinting given by the percolating melt. This implies that the interaction between xenoliths and the melt occurred before the sampling of the basanite and lasted enough to permit this metasomatism. Considering the geothermobarometer of Putirka (2008), based on the equilibrium between Cpx and melt, and given the Rhodes diagram in Fig.34, clinopyroxenes (core and rims) appear in equilibrium with melts with Mg# in the range 0.70-0.45. Notably, the REE pattern of the calculated melts obtained by these Cpx (Fig.41) well approximate those of the glasses, but at lower concentrations. This suggests that the CPX crystallized when the glass was a less evolved melt. Moreover, all the fractionated Cpx appears compatible with one fractionation trend. However, the glasses (all evolved; MgO=1.5-0.2wt%) spread from phonolites to trachyte. It is important to observe that in the less alkaline glassy patches (trachytes), the interaction between glass and orthopyroxene is evident.

Differences between metasomatic and magmatic Cpx are negligible, but it is possible to observe two main features considering Al and Ca contents. A group, composed of mostly mantle Cpx cores and a few magmatic Cpx cores, shows an increase in CaO coupled with an Al₂O₃ decrease that starts from the composition of the Cpx calculated for the DMM by Workman & Harte (2005) and reaches the CaO content of 22.0-23.0 wt%. Considering this high CaO content, most of the magmatic Cpx (core and rims) as well as most of the mantle Cpx rims plot in a group characterized by a constant CaO and variable Al₂O₃. Moreover, in Fig.50 it is evident that the mantle Cpx cores, starting from the DMM Cpx composition, increase in their Ti content with the decrease of Mg#, staying below the value of 1.0 wt% in TiO₂. However, all the other Cpx (magmatic cores, magmatic rims and mantle rims), show a great spread in TiO₂ and Mg#, and for Mg# values similar to the metasomatized group, their TiO₂ span from 1 to 5%.

These features suggest that few of the magmatic cores (plotting on the metasomatic trend of Fig.49, close to the Cpx DMM) could be considered fragments of mantle Cpx used as crystal seed (Fig.28) and that most of the mantle Cpx rims, instead, could be considered magmatic.

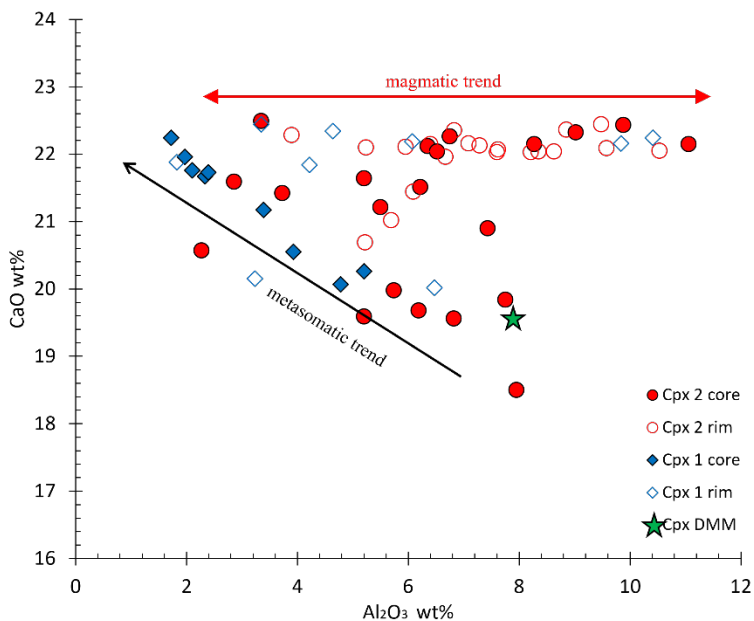


Figure 49: bivariate diagram showing CaO and Al_2O_3 content in the analyses Cpx. Concentrations expressed as wt%. Black and red arrows represent the proposed metasomatic and magmatic trends, respectively.

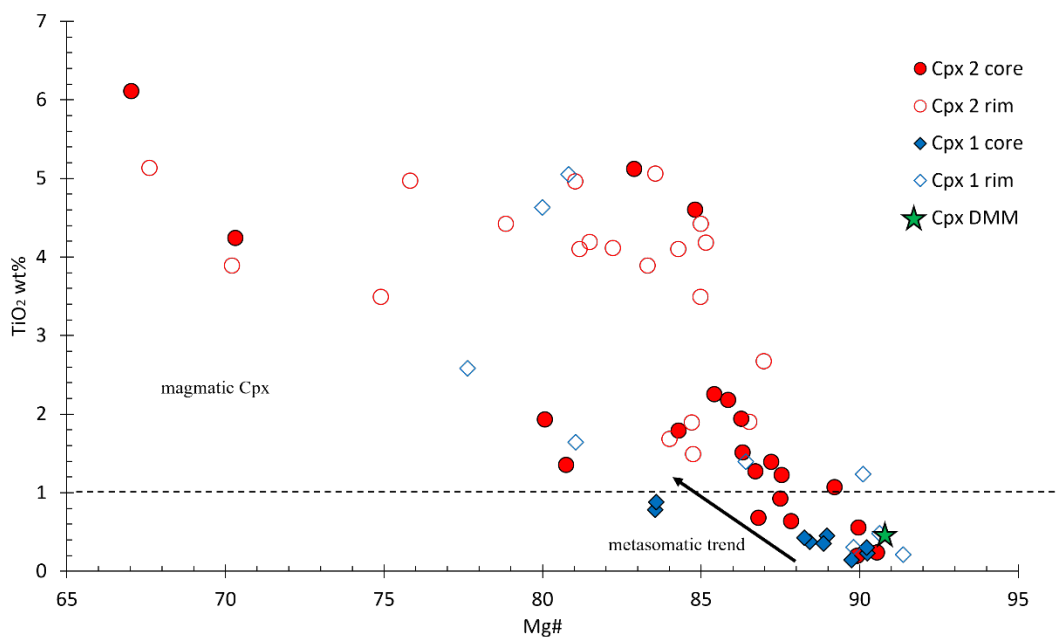


Figure 50: Mg# vs. TiO_2 (wt%) content for our clinopyroxenes.

Considering T and P calculations we made on mantle phases, the results in Table 5 show two main clusters: pressures of 11-17 kbar (sample FN30 and one test on FN38) and 4–7 kbar (FN41 and FN38). Notably, the first is perfectly in the range proposed by Rivalenti et al. (2000) for mantle xenolith from FN, while the second group of pressures is consistent with the presence of plagioclase in glassy patches and is aligned with the result of the amphibole-melt geobarometer (5.5 Kb) we applied to amphibole analysis. Combining petrographic evidence (i.e. spinel and plagioclase presence inside glassy patches) and chemical considerations (see above in the text) we hypothesize that our glasses experienced a two-stage permanence in the lithospheric mantle prior to being exhumed by the São José basanites together with mantle xenoliths. One at higher pressures (10-12 Kb), allowing the fractionation of spinel along with olivine and Cpx, which could be the only step experienced by our mantle xenolith FN14, as it lacks plagioclases. Moreover, having the bigger and better formed Cr-spinel octahedrons, this sample probably stood in this pressures range for a longer period after the infiltration of the melts. The second stage, at pressures of 5 Kb on average, is when plagioclase crystallized in the glassy patches where spinel, olivine and Cpx were already present. Moreover, the fractionation of Cpx raised the alkalinity of the residual melt, until it was sufficiently high to allow the partial assimilation of orthopyroxene. This assimilation was locally variable, based on the availability of the phase (surface of Opx in contact with glassy patches) and affected the composition of the melt mainly in its silica content.

8.3 Glasses

The first consideration over the composition of the analyzed glasses is that they do not represent the infiltration of the hosting Na-basanite as they are potassic (average $K_2O=7.33$ wt% vs. 1.1 wt%), with different elemental patterns. Indeed, we performed fractional crystallization simulations through MELTS (Ghiorso & Sack, 1995) using as input the composition of Sao José basanites and all the other magmatic formations of the island (using data from Lopes & Ulbrich, 2015) but it was not possible to reach a composition similar to the one of our glasses, nor generating the same mineral assemblage we see in the glassy patches. We made calculations starting with a temperature of 1200°C until 850°C at variable fO_2 .

Glasses are quite evolved, spanning from trachyte to phonolite, as shown in the diagram in Fig.40, with the exception of only three spot analyses on glasses from sample FN41, that plot in the latite field, although having a low MgO concentration (0.06 wt% on an average of 0.80), being particularly rich in CaO (6.64 wt% vs. an average value of 1.65 wt%) and slightly richer in Al_2O_3 (25.71 wt% vs. average concentrations of 23.27 wt%). Even though they show a similar degree of evolution, looking at the R1-R2 diagram (Fig.40) they apparently belong to different magmatic suites, characterized by different alkalinity. This seems to be independent of the presence of plagioclase and is in contrast with the 3D tomographic observations, that show glasses have a high connectivity density compatible only with one percolating melt. Finally, all the glasses present a similar amount of olivine and Cpx, consistent with an equilibrium crystallization from a single less evolved melt. As observed above, this feature could be due to the partial assimilation of orthopyroxene by the melt. This occurred after the fractionation of both Ol and Cpx when the residual melt reached sufficiently high alkalinity. The orthopyroxene has variably added silica to the glassy patches, depending on its distribution inside the xenolith, moving the classification of glasses from phonolite to trachyte without influencing the trace elements patterns.

The general high content in Al_2O_3 and K_2O could be due to the presence of K-bearing hydrate phases (for example phlogopite) in its mantle source. Such kind of supply cannot be related to the depleted asthenosphere, nor to a mantle plume, because the breakdown of these phases ranges from 65 Kb to 80 Kb according to Konzett & Ulmer (1999).

Considering REE and trace elements, glasses show a similar pattern to the K-series of Rémedios formation (see chapter 4.4), thus we speculate they may have a common source. The same speculation was made by Rivalenti et al. (2000) who, looking at the isotopic signature of mantle Cpx, stated that it is similar to the one of the Rémedios formation, suggesting a mixing between a DM and EMII reservoirs. This is consistent with what we observed and discussed in the previous section. Assuming the glasses permeating the xenoliths as the “EMII bearing” component, their considerations are in agreement with the kind of metasomatism we are reporting in the mantle phases, as visible in the REE and IE patterns of both spinels, olivine and clinopyroxenes. As a matter of fact, the glass calculated from their Cpx analyses is similar to the one we analyzed in our samples (Fig.51) even if there are some differences, that may be due both to the K_d values chosen in the calculations and the variability in the metasomatism experienced by the phases.

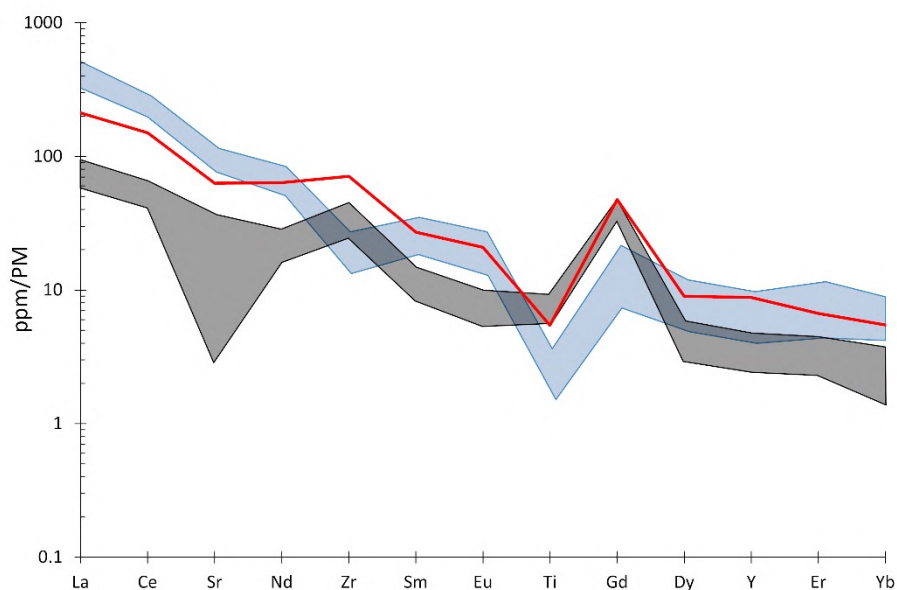


Figure 51: our glasses (black field) compared to the ones calculated by Rivalenti et al. (2000) from mantle xenolith Cpx (blue field). Red line representing the trachyandesite of Rémedios (Lopes & Ulbrich, 2015). Data normalized to the PM of Sun & McDonough (1989).

Calculations we made on our clinopyroxenes using the K_d from Fedele et al. (2009) testify that our melt is the source of metasomatism experienced by Cpx in mantle xenoliths from Fernando de Noronha. As visible in Fig.52, all our Cpx, both mantle phases and magmatic ones give as result a pattern similar to our glasses. The only difference is in the percentage of fractionation, as the pattern for calculated melts from less enriched Cpx is below the one of the observed glasses, while for the most enriched clinopyroxenes the pattern plots at concentrations higher than the observed glasses, which are their residual melt. Notably, calculated melts show the same enrichment in LREE with respect to an OIB (mean La/Nd=1.72 for calculated glass, 0.96 for OIB) as the glasses analyzed (La/Nd=1.67 in average).

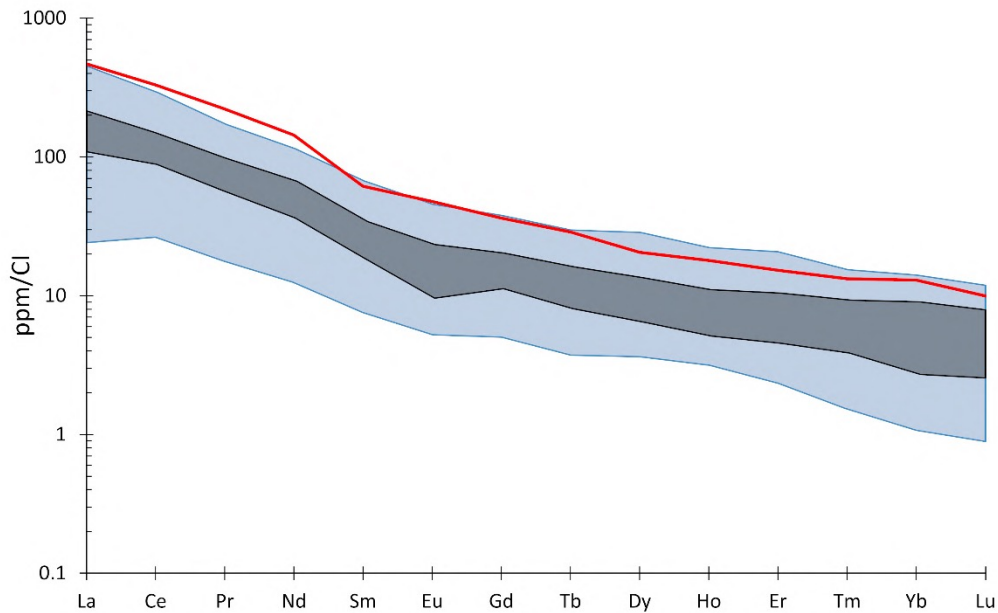


Figure 52: REE patterns of the calculated glasses from our Cpx (blue field) and pattern of the actual glasses (black field). In red the trachyandesite of Rémedios (Lopes and Ulbrich, 2015). Data normalized to the Chondrite of Boynton (1984).

The similitude with Rémedios K-series has been found even by the mass balance, done using the composition of the melts, the associated magmatic phases crystallized inside the glassy patches (olivine, Cpx, plagioclase, spinel and apatite) and the mantle orthopyroxene that we suppose has been assimilated. The best result includes the assimilation of Opx in the percentage of 5% and the fractionations of Ol (15%), Cpx (15%), Pl (10%), Sp (3%) and apatite (1%). Anyway, obtained results (Fig.53) appear slightly more alkaline with respect to the Rémedios K-series. This may be due to a major fractionation of Ol with respect to Cpx, otherwise to what was calculated.

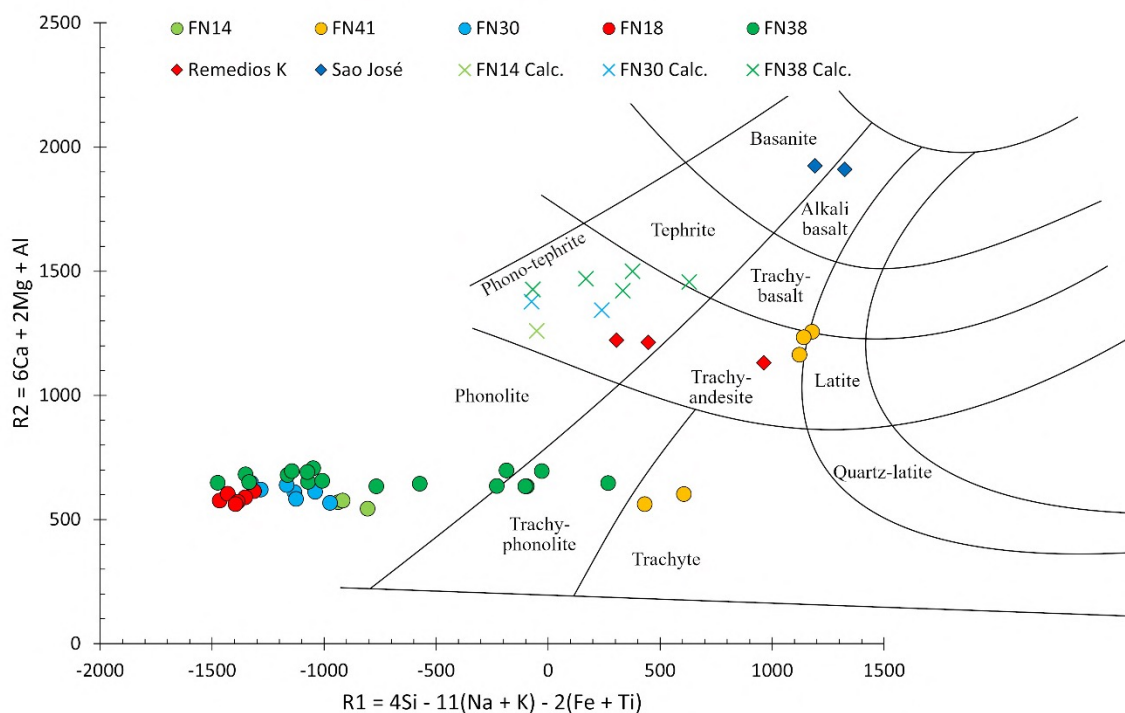


Figure 53: De La Roches diagram (1980) showing the composition of the glasses before and after mass balance calculations ("Calc" in the legend). Sao José and K-Rémedios compositions are given for comparison (data from Lopes & Ulbrich, 2015).

To explain all the chemical (major and trace elements) features of the studied glasses, we invoke the contribution in their genesis of continental lithospheric fragments stretched and located beneath the archipelago. Notably, for Cameroon and Fernando de Noronha archipelago, Guimaraes et al. (2020) suggest a perfectly symmetric geodynamic situation. However, no K-magmatism occurred in the Cameroon line and the authors do not consider the immobility of the African plate since Cretaceous time (ex. Ernesto et al., 2002). This implies for the south American platform a double velocity with respect to the one calculated looking at the Mid Atlantic Ridge. This immobility of the Atlantic boundary of the African continental plate could be related to the three main cratonic areas that face the Atlantic coast (i.e. West African, Congo and Kalahari cratons), which present cratonic roots exceeding the depth of 350 km (Begg et al., 2009). This stressing movement showed by the south American plate could favor a lithospheric stretching, that, being less depleted with respect to the asthenosphere and being captured by the latter, easily could melt. This melt should have the features observed in the studied xenoliths (glasses and metasomatized phases). The stretching of the continental lithosphere is also supported by the recent study of Lamarque & Julià (2019), which highlighted that in front of the FN archipelago there are anisotropies oriented sub-perpendicular to the plate margin, which suggest to the authors the presence of a “frozen” contaminant in the oceanic lithosphere due to stretching and rifting during the south Atlantic opening.

8.4 The mantle beneath Fernando de Noronha

Resuming all that was discussed above, our results are in agreement with some of the observations made by previous work on FN mantle xenoliths (Rivalenti et al., 2000; Liu et al., 2019a, 2019b). Makes an exception for what was reported by Kogarko et al. (2001), as we did not find any evidence of carbonate metasomatism.

Metasomatism induced by diffuse percolation of our glasses affects all the phases composing xenoliths, causing variation not only on trace element patterns but even on some major elements, such as the trend of increasing CaO in olivine and Cpx, and the increase in TiO₂ in spinel and Cpx. Notably, these are exactly the anomalous variations reported for some mantle xenoliths from FN in the literature and attributed to reactive melt percolation (Liu et al., 2019a). Moreover, this kind of metasomatization process could raise the content of Cpx and olivine in mantle xenoliths, considering that the fractionation of olivine may be increased by the assimilation of Opx.

The composition of the glasses themselves testifies a parental relationship at least with the K-series of the Rémedios formation, we want to highlight the real extent of the potassic magmatism in the archipelago is hard to be defined. As stated in the geological introduction, in our opinion, spilitization processes have not been sufficiently investigated in the outcrops, and the diffuse presence of zeolites may affect chemical WR analyses, leading to incorrect classifications. Anyway, considering the strongly potassic composition of our melts and their Al₂O₃ content, we suggest that hydrous potassic phases melted, such as phlogopite and/or other micas. This kind of source cannot come from a depleted mantle like the one lying underneath a common oceanic crust, thus the oceanic lithosphere has to be contaminated during the opening of the Atlantic Ocean as a consequence of the partial melting of a lithospheric stretching.

This is a process that could be particularly likely for the South American plate, as it experienced, since the opening of the Atlantic ocean, a very fast and variably directed motion, as stated by Ernesto et al. (2002) and reported in Fig.54.

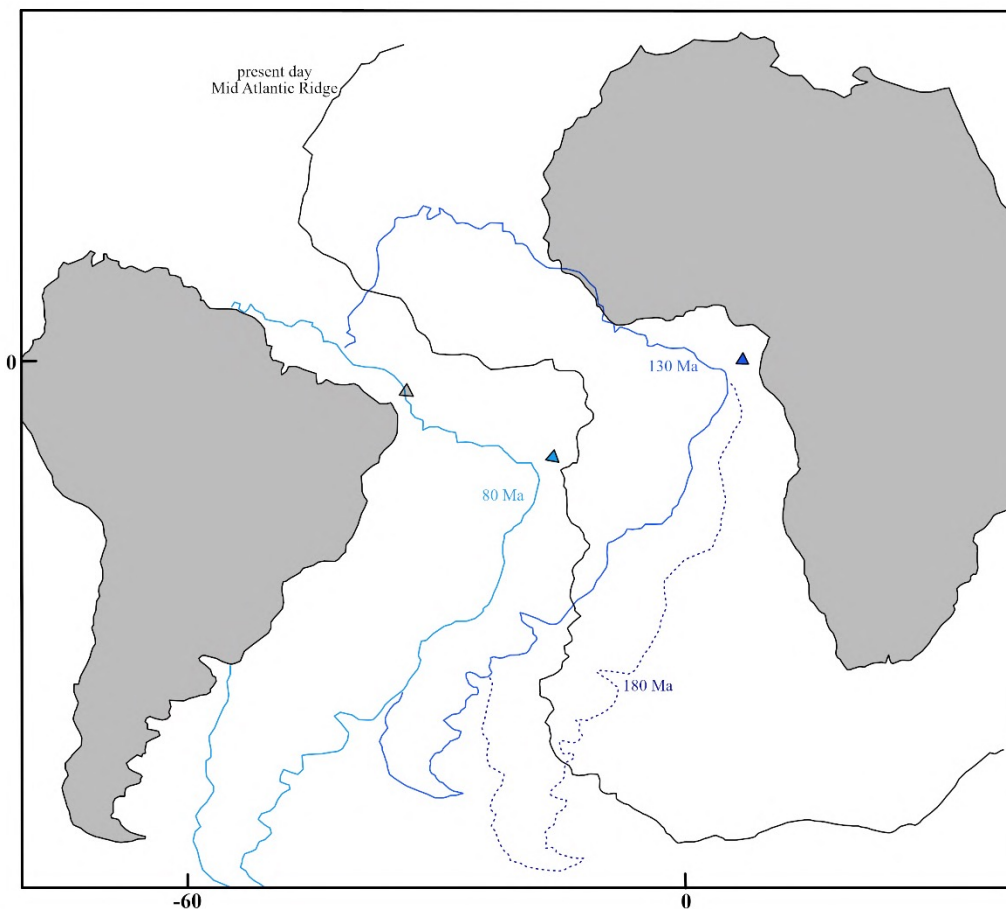


Figure 54: paleopositions of the South American plate from Ernesto et al. (2002). Fernando de Noronha archipelago are represented as triangles, coloured according to the motion of South American plate. Present-day configuration of South America and Africa are given in grey, present-day MAR as a solid black line.

Considering the works of Klocking et al. (2020) and Guimaraes et al. (2020), the cause of the melting of this lithospheric contaminant may be the simple upwelling of the asthenosphere that was likewise stretched during the opening of the Atlantic ocean. Interestingly, a mechanism of edge-driven convection as the one explained by King & Anderson (1998) could drive the asthenospheric upwelling and facilitate at the same time the lithospheric thermal erosion and delamination. Notably, the global S-wave tomography models suggest that edge-driven convection is geometrically favorable for Fernando de Noronha, as reported by King (2007).

Consequently, to the melting of the mica-rich EMII source, larger volumes originated the magmas that are expressed at the surface by the Rémedios K-series. At the same time, some of the melt started fractionating spinel, olivine and clinopyroxenes and percolated upwards, as small volume

melts, stationing at an average pressure of 5Kb. Those melts metasomatized mantle phases and went further with fractionation of olivine and Cpx, forming even plagioclases, until the alkalinity was sufficient to assimilate orthopyroxene. Finally, the basanites generated deeper by increasing heating of the upwelling asthenosphere, sampled a suite of xenoliths at various depths in a range between 20 and 5 Kb and brought them to the surface.

The model that summarize all these features is summarized in Fig.55. Both of the previously existing models of Liu et al. (2019a) and Guimaraes et al. (2020) may be valid to explain the genesis of the sodic magmatism, as the basanite that brought to the surface our mantle xenoliths for example. However, the model of Guimaraes et al. (2020) is more effective to justify the presence of continental lithospheric fragments beneath the archipelago, supporting the edge-driven convection phenomena that on one hand favors the lithospheric stretching and on the other allow the melting of these fragments because of adiabatic raise.

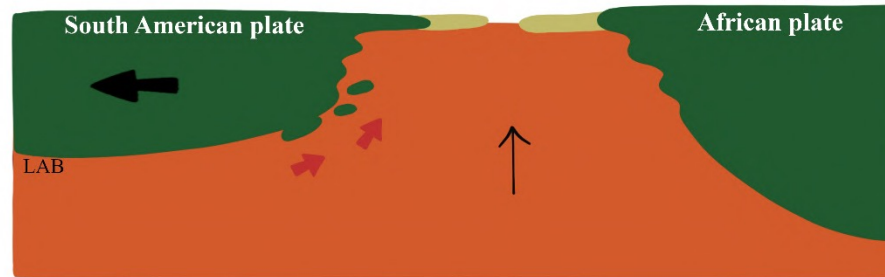
For what concerns the metasomatic processes we agree with some of the considerations present in the model of Liu et al. (2019), metasomatism started from depths of about 60 km, but the presence of plagioclase inside most of the glassy patches here studied suggests us that the metasomatic event continued at least up to 9-10Kb. From our geobarometric calculations, this may be occurred even up to 4-5 Kb, thus to depths very close to the oceanic MOHO.

Figure 55 (following page): a schematic framework for the origin of the FN magmatism and mantle metasomatism, not to scale. LAB = lithosphere-asthenosphere boundary; FN = Fernando de Noronha archipelago; red crosses show the location of the here studied mantle xenoliths. Green volumes are the continental lithosphere, while light green represents the oceanic lithosphere. Notice the red arrows showing the supposed edge-driven convection mechanism, emphasising lithospheric stretching during the South American plate movement (black arrows). At around 12 Ma the continental lithospheric contaminant melted, forming the FN K-series and generating the metasomatizing melt here studied (green arrows). At ca. 9 Ma, Sao José basanites sampled our mantle xenoliths.

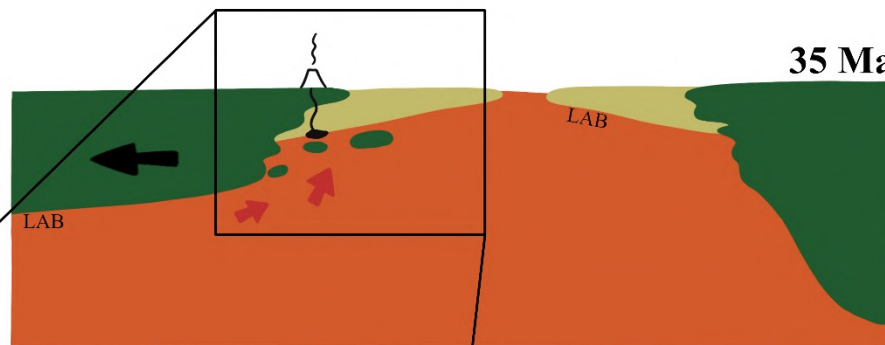
200 Ma



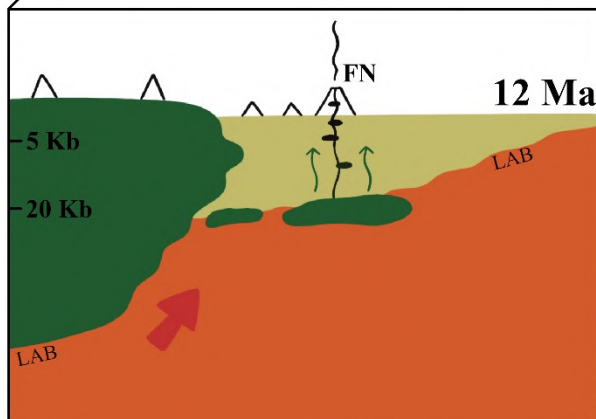
100 Ma



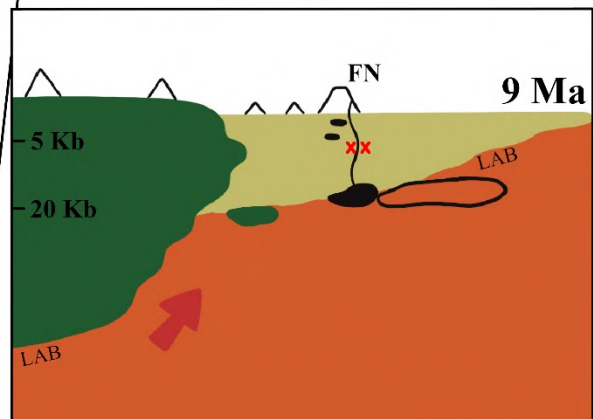
35 Ma



12 Ma



9 Ma



9. Conclusions

To investigate the origin of mantle metasomatism in the Fernando de Noronha archipelago, we investigated a suite of mantle xenoliths coming from the Sao José basanites. We found 5 samples rich in glassy patches, showing several phases fractionated inside melts. These magmatic crystals are all euhedral to subhedral in shape and are an assemblage composed by Cr-spinel, olivine, clinopyroxene, variably present plagioclase, rare apatite and, in one sample, amphibole. Moreover, glassy patches show evidence of degassing through the presence of gas bubbles now fulfilled by zeolites. Petrographic observations testify spinel was one of the first phases to fractionate, while plagioclase and apatite were the latter.

The application of 3D X-ray computed microtomography allows us to obtain three-dimensional models of the five selected samples and permit us to segment the different phases composing xenoliths. Glass in particular appears as fully scattered inside samples, with high values of interconnectivity. High-resolution analyses (2.5 to 0.9 μm of pixel sizes), conducted with synchrotron light radiation X-ray $\mu\text{-CT}$, show that glasses are connected even via intergrain spaces, thus surrounding mantle phases composing the xenolith. Spinel shows different habitus, being present as large holly leaf anhedral crystals, or small crystals inside glassy patches. In the latter case, it may be euhedral (in full octahedrons), skeletal-like and subrounded, depending on the sample.

Mineral chemistry stressed that glasses metasomatized quite all the mantle phases, in some cases recycling mantle crystals inside the glassy patches, that act as crystal seeds for newly formed euhedral phases. Some major elements seem to be particularly effective in the identification of this metasomatism, such as CaO in both olivine and Cpx, or TiO_2 in spinel and clinopyroxene. For all the phases, REE and IE patterns are quite similar among different samples, testifying they all crystallized from the same source, as shown by La/Ce ratios. IE patterns indicate various degrees of enrichment with respect to the DMM tending towards the composition of our glasses.

Analyses of glassy patches show that melts are K-rich, quite evolved and with high concentrations of Al_2O_3 . They are different from the hosting basanites in both major and trace element patterns, being instead quite similar to the Rémedios potassic series. Interestingly, glasses show similarities with the average OIB values only for HREE, while they are all enriched in LREE with respect to the OIB. The same is true for the melts calculated starting from the composition of our Cpx, both mantle and magmatic, testifying that the mantle ones were metasomatized by the glasses.

These findings shed light on the behaviors of potassium-rich small volume melts inside the mantle and suggest lithospheric stretching played a fundamental role in the genesis of this magmatic province. The source of these melts indeed has to lay in the lithosphere at low depths, as the chemistry of the glasses suggests a K-micas rich reservoir, consistent with isotopic signature of both archipelago magmatism and previous studies on metasomatized mantle phases.

Coupling our study with the last made on equatorial Atlantic OIB, the presence of the so-called FN plume seems to be unrealistic. Instead, a simple mechanism of edge-driven convection may have guided the asthenospheric upwelling, favoring the lithospheric stretching and triggering the melting of the potassic source. Subsequent pervasive (as stated by 3D textural models) percolation of some of this melt metasomatized the mantle phases and changed both modal and chemical composition of the mantle throughout assimilation of orthopyroxene and fractional crystallization of spinel, olivine, clinopyroxene, plagioclase (at the lower pressures), apatite and occasionally amphibole.

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Multi-scale and multi-modal imaging study of mantle xenoliths and petrological implications

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Abstract

The accurate textural characterization of mantle xenoliths is one of the fundamental steps to understand the main processes occurring in the upper mantle, such as sub solidus recrystallization, magmatic crystallization and metasomatism. Texture, as well as composition and mineralogy, reflects the temperature, pressure, stress conditions, melting and/or contamination events undergone before and during the entrapment in the host magma. For these reasons, characterizing the three-dimensional (3D) texture of silicate, oxide, sulfide and glass phases has great importance in the study of mantle xenoliths. Here we performed a multi-scale and multi-modal 3D textural analysis based on X-ray computed microtomography (μ -CT) data of three mantle xenoliths from different geodynamic settings (i.e. mobile belt zone, pericraton, oceanic hotspot). These samples have been selected to represent different, variably complex, internal structures, composed by grains of different phases, fractures, possible fluids and voids of different sizes. We used an approach structured in increasing steps of spatial and contrast resolution, starting with laboratory-based X-

ray μ -CT imaging (working at spatial resolution from a few tens of μm up to about 10 μm) and moving to high-resolution synchrotron X-ray μ -CT at the micron scale.

We performed a 3D characterization of mantle xenoliths comparing the results with the analysis of conventional 2D images (thin sections) obtained by optical microscopy and simulating the random sectioning of several thin sections in order to estimate the probability of a correct modal classification. The obtained 3D models allow us to extract several textural information that cannot be quantified using solely the thin sections: spinel layering, distribution of silicic glass and related vesicles. Moreover, high-density volumes identified as sulfides were detected in two xenoliths, showing no relation with the spinel layering in one case and a preferential concentration along fractures in the other one. Given the variety of textures and mineralogy of mantle xenoliths worldwide, the presented results are used as a suggestion of experimental and analytical protocol for the characterization of these materials.

Keywords: 3D microcomputed tomography; X-ray synchrotron-based μ -CT; mantle xenoliths; petrology.

1. Introduction

Investigating the nature of the mantle throughout the study of mantle xenoliths allows to better constrain the structure of the lithospheric mantle, the mechanisms that generates melts in the mantle as well as the evolution of the lithosphere beneath regions where no samples were exposed by tectonic activity (e.g., Ringwood, 1991; Coltorti et al., 2000; Pearson et al., 2003; Kiseeva et al., 2017). The composition, mineralogy and texture of mantle xenoliths reflect the temperature, pressure, stress conditions and melting or contamination events undergone before or during the entrapment in the host magma (Pearson et al., 2003). In particular, metasomatism affects the chemistry of the original mantle rock, decreasing its solidus temperature and leading to the generation of a wide spectrum of magmas. Studying the distribution of small volume melts like glassy patches and veins, as well as the texture of silicate, oxide and sulfide phases in samples from the upper mantle, bears a great potential in the study of mantle metasomatism (Coltorti et al., 2000; Hughes et al., 2016; Blanks et al., 2020).

In a conventional thin section of an anisotropic and/or inhomogeneous rock, the resulting two-dimensional (2D) texture depends on the orientation of the random sectioning plane. In some cases,

this might hamper the appropriate characterization of the rock leading to possible overlooking of internal structures (like quenched melt channels, stress-driven fractures or voids, preferential distribution of some minerals, etc.) that bear important information about the processes occurring at depths. Extending the textural analysis of mantle xenolith to the three-dimensional (3D) scale is therefore a potentially powerful tool in Earth science (Carlson, 2006).

Among analytical methods for 3D imaging of geological samples, X-ray computed microtomography (μ -CT) already showed to be of much use (e.g., Baker et al., 2012a; Cnudde and Boone, 2013; Kyle and Ketcham, 2015). Being a non-destructive technique, it provides a considerable benefit when working with samples that are rare and valuable as mantle xenoliths. It allows to determine volumetric ratios and 3D spatial distribution of the different minerals, glasses and voids (Ketcham & Carlson, 2001, Baker et al., 2012b; Polacci et al., 2015; Arzilli et al., 2017; Yao et al., 2020). In previous studies of mantle xenoliths, laboratory- and synchrotron-based μ -CT techniques have been used, for example, to map 3D networks of interconnected glass (Troll et al., 2012; Patkó et al., 2020), to determine shape and dimensions of spinel-pyroxene clusters and the variability of spinel textures (Bhanot et al., 2017) and to quantify the distribution of geologically and economically important minerals (e.g., diamonds and sulphides; Howarth et al., 2015; Logvinova et al., 2015).

Considering a xenolith suite from a given locality, μ -CT could provide even more insights if it was systematically applied in natural samples before any destructive analytical technique, allowing for a first characterization that can help identifying possible textural and/or mineralogical heterogeneity within the samples. This would allow to locate the precise volume to be extracted for classic thin section petrography and chemical analyses. Despite its potential, this technique is still rarely used by the petrological community studying mantle xenoliths. From one hand, this might be due to the limited access to such facilities. On the other hand, given the large variability of size and X-ray attenuation coefficients of the phases within mantle xenoliths, this might reflect the lack of a protocol providing the right instrumental and processing workflow for each petrological information that need to be extracted.

The aim of this work is to investigate some specific petrological features of mantle xenoliths through μ -CT using a multi-scale approach. With this in mind, we performed a 3D textural analysis on three mantle xenoliths from different geodynamic settings. Due to the high complexity of their internal structure - made by grains of different phases, featuring fractures and containing possible fluids and voids of different sizes - we used an experimental protocol structured in increasing steps of spatial and contrast resolution. We started with μ -CT imaging based on laboratory sources and then we

moved to a synchrotron radiation one to achieve a higher contrast between the different phases and a spatial resolution at the micron scale.

2 Materials and Methods

2.1 Sample selection and geological background

Sample	Provenance	Dimensions (mm)	Description	Related magmatism
MG10x	Mandalgovi, Mongolia	45 x 37 x 21	Coarse grained peridotite	Alkali basalt
Bi4	Bou-Ibalrhatene, Morocco	50 x 40 x 20	Coarse grained peridotite, crumbly	Alkali basalt
FN38	Fernando de Noronha, Brazil	48 x 19 x 13	Coarse grained peridotite, glass-bearing	Basanite

Table 1: Sample description

We selected three mantle xenoliths from alkali basalts and basanites (Table 1). Mantle xenolith MG10x comes from a volcanic edifice (45°38'55.56N; 106°22'19.38E) south of Mandalgovi, Sajncagaan District, Central Mongolian plateau. The edifice belongs to an Upper Cretaceous - Eocene volcanic district (Yarmolyuk et al., 2019) located along the Mongol-Okhotsk Suture, which is related to the closure of the Mongol-Okhotsk Ocean around middle Jurassic times (Sheldrick et al. 2020). Since the crustal thickness in this area is ca. 45 km (Guy et al., 2014), it is estimated that the depth of provenance of this xenolith is greater than 45 km. The original xenolith size was approximately 45x37x21 mm³ and no deformation structures, mineralogical layering or any other inhomogeneity were detectable by the naked eye or using hand lenses.

Xenolith Bi4 comes from the Bou-Ibalrhatene maar (33°20'11.52''N - 5°3'24.16''W), middle Atlas basaltic province, Morocco. In this locality, mantle xenoliths are found in Plio-Quaternary alkaline maar deposits and are porphyroclastic to protogranular spinel-lherzolites, sampled at depths from 30 to 40 Km (Lenaz et al., 2014). They are characterized by a broad range of chemical heterogeneities testifying the metasomatized nature of the upper mantle in the pericratonic area of Morocco (Lenaz et al., 2014, 2019; Chanouan, 2017), where the term pericratonic refers to an area bordering the West African Craton. Sample size was approximately 40x10x9 mm³ and was a

piece cut from a larger xenolith embedded in the host basalt. A major fracture was visible, but no mineralogical layering or any other inhomogeneity were detectable by the naked eye or using hand lenses.

The FN38 xenolith comes from a basanite flow of the Sao José formation, Sao José island, NW of the Brazilian archipelago of Fernando de Noronha. These basanites include abundant peridotitic xenoliths and have $^{40}\text{Ar}/^{39}\text{Ar}$ ages in the range 9.0 ± 0.2 to 9.5 ± 0.4 Ma (Perlingeiro et al., 2013; Lopes et al., 2015). The entire archipelago has a main NE-SW trending course and belongs to the vast volcanic edifice positioned along the Fernando de Noronha ridge, which is interpreted as an OIB originated by a plume (Fodor et al., 1998; Lopes et al., 2015). Previous studies on the Fernando de Noronha mantle xenoliths suggested that they have been samples from the depth range 30–75 Km (Princivalle et al., 1994; Rivalenti et al., 2000). The original sample size was approximately $48 \times 19 \times 13 \text{ mm}^3$. Also in this case, no deformation structures, mineralogical layering or any other inhomogeneity were detectable by the naked eye or using of hand lenses.

2.2 Experimental

Xenoliths have been characterized through polarized light microscopy of thin sections and by X-ray computed microtomography (μ -CT). For each sample, the characterization through μ -CT included three to four steps with increasing spatial and contrast resolution.

Step A involved cone-beam polychromatic μ -CT imaging at the Multidisciplinary Laboratory (MLab) of the "Abdus Salam" International Centre for Theoretical Physics (ICTP, Trieste, Italy) (Tuniz et al., 2013). In this step we analysed the largest available volume for each sample, in order to obtain a first complete 3D reconstruction of the xenolith microstructure. The tomographic scanning of all specimens was carried out by using a sealed microfocus X-ray source (Hamamatsu L8121-03) at a Voltage of 110 kV, a current of 90 μA and with a focal spot size of 7 μm . The X-ray beam was filtered by a 0.1 mm-thick copper filter. A set of 1440 radiographs (projections) of the xenoliths was recorded over a total scan angle of 360° by a 12-bit, 2400×2400 pixels flat panel detector (Hamamatsu C7942SK-25, pixel size: 50 μm). The virtual axial slices were reconstructed in 32-bit Tiff format, with an isotropic voxel size ranging from 21 to 30 μm (see Table 2) and using the commercial software DigiXCT (DIGISENS, France).

Step B involved cone-beam polychromatic X-ray imaging measurements performed at the TomoLab station of the Elettra synchrotron facility in Trieste, Italy (Mancini et al., 2007; Polacci et

al., 2009). The instrument is equipped with a sealed microfocus X-ray source (Hamamatsu L9181) with a minimum focal spot size of 5 μm and can operate both in absorption and phase-contrast modes (Wilkins et al., 1996; Zandomeneghi et al., 2010). A set of 2400 projections was acquired for every sample, over a total scan angle of 360° , by a 12-bit, water-cooled, 4008×2672 pixels CCD camera (Photonic Science XDI-VHR, UK) with a gadolinium oxysulfide scintillator screen coupled to a fiber-optic taper. A 2×2 binning was applied to the detector pixels in order to improve the signal-to-noise ratio. Scanning conditions were: voltage = 130 kV, current = 61 μA , filter = 1.5 mm-thick Al foil, exposure time per projection = 6.5 s. The tomographic reconstruction was made by the free software Nrecon 1.7 (Bruker, USA) in 16-bit Tiff format with an isotropic voxel size ranging between 6.25 and 17.5 μm , (see Table 2). In this step we focused on some volumes of interest (VOIs) inside the xenoliths, so the probed volumes are smaller than the entire samples.

Both software tools used for tomographic reconstruction in steps A and B are based on the FDK algorithm (Feldkamp et al., 1984) for the cone beam geometry of the X-ray beam.

Steps C and D involved the use of synchrotron radiation microtomography at the SYRMEP beamline of Elettra (Tromba et al., 2010). Cylindrical samples of 4 mm in diameter were drilled or cut out of the sub-volumes analysed in Step B. At SYRMEP, a bending magnet source delivers a nearly-parallel, laminar section X-ray beam with a maximum area of $160 \times 6 \text{ mm}^2$, at a distance of ca 24 m from the source. The beamline is equipped with a Si (111) double crystal monochromator allowing to work at energy between 8.3 and 40 keV. It is also possible to operate in filtered white-beam ('pink') mode. Our experiment was performed in the 'pink' modality using as filters 1.5 mm-thick Si plate plus a 1.0 mm-thick Al one, giving a mean energy of the X-ray spectrum of ca 27 keV. For each scan 1440 projections were acquired over a total scan angle of 180° during a continuous sample rotation. The detector used is a 16-bit, water-cooled, 2048×2048 pixels sCMOS macroscope camera (Hamamatsu C13440-20CU) lens-coupled to a 17 μm -thick GGG:Eu scintillator screen. The $\mu\text{-CT}$ experiments were carried out in propagation-based phase-contrast mode (Cloetens et al., 1997; Baker et al., 2012a; Polacci et al. 2015) setting a sample-to-detector distance of 150 mm. Steps C and D involved the acquisition of images with an effective pixel size of 2.5 and 0.9 μm , respectively. While on step C we analysed samples in their entire diameter, in step D we imaged sub-volumes of interest (region of interest $\mu\text{-CT}$). The tomographic reconstruction was carried out by using the Syrmep Tomo Project (STP) 3.1 software suite developed at Elettra (Brun et al., 2015) based on the filtered back-projection algorithm (Herman, 1980) and powered by the ASTRA Toolbox (van Aarle et al., 2015). Prior to tomographic reconstruction, a single-distance phase-retrieval algorithm (Paganin

et al., 2002) was applied to the projection images. The δ/β parameter (ratio between the departure from unit of the real part and the imaginary part of the refraction index of the investigated sample material) was optimized for the different samples. This optimisation was done on a ad-hoc base in order to increase the visibility of the phases of interest.

Every sample was cut in order to obtain thin sections of about 30 μm with polished surfaces. Thin-section preparation was performed at University of Padova, Department of Geosciences. 2D textural analysis of samples was carried out in the University of Trieste, Department of Mathematics and Geosciences with a Leitz Wetzlar optical microscope equipped with 5 lenses of, respectively, 2.5/ $0.08\times$, 6.3/ $0.20\times$, 16/ $0.43\times$, 25/ $0.55\times$, 40/ $0.70\times$ magnification and a Canon EOS 700D camera. All the images of thin sections were processed with the open-source software Gimp (Gnu Image Manipulation Program).

For sample MG10x the μ -CT protocol described in step A has been applied to the whole xenolith before cutting it for thin section. In this case, the preliminary 3D imaging analysis showed a preferential distribution of a layered phase (i.e., spinel layering; see below) and therefore the rock chip (size: 22x20x14 mm³) used for the subsequent μ -CT steps and thin section petrography was cut out in a way to have its long axis perpendicular to the layering. For samples Bi4 and FN38, thin section petrographic analyses and μ -CT experiments were performed on two different fragments of the same xenoliths. No oriented structures have been observed for these two samples.

Sample:	Voxel sizes (μm)			
	MLab laboratory	TomoLab laboratory	SYRMEP beamline	
	<i>step A</i>	<i>step B</i>	<i>step C</i>	<i>step D</i>
<i>MG10x</i>	30	10	2.5	
<i>Bi4</i>	21	6.25	2.5	0.9
<i>FN38</i>	23.3	6.7	2.5	0.9

Table 2: Voxel size for the different microtomographic data reconstructed for the mantle xenoliths in this study.

2.3 3D image processing and analysis

One of the main steps in μ -CT data processing and analysis is the definition of a representative elementary volume (REV) which averages all the variable properties of the sample. Considering the nature of any mantle xenolith, which represents a single piece of the lithospheric mantle suspended at the time of its eruption, every sample is equally significant and, except for the peripheric layer which may be altered by the hosting basalt, the whole volume needs to be investigated. For these reasons, we believe the multi-scale approach here presented is the only way for being sure to analyze a volume that can be considered a REV. At every 3D imaging step, we isolated a volume of interest (VOI) as large as possible, verifying that in the subsequent step we were going to analyse a part of the sample still representative of all its properties.

For all μ -CT setups employed, the virtual sections (both raw and processed data) were visualized by using the open-source software ImageJ (Schneider et al., 2012) while the 3D visualization, through isosurface or volume rendering tools, was performed by the Dragonfly software (ORS, Canada), version 2020.2 for Windows, using a free-of-charge license for academic use. Image processing and analysis were also performed by using the Dragonfly software.

The first step of data processing was the 3D image segmentation carried out using the corresponding panel integrated in the software, applying to the grayscale an automatic threshold or a locally adaptive threshold in the more complex cases. Sometimes the complexity of data, or a too low-density contrast required a semi-automatic segmentation coupled with interpolation operations. After segmentation a cleaning procedure was applied to exclude from the segmented region of interest (ROI) eventual small defects, undesired and/or unphysical objects as outliers or noise. Segmentation and cleaning were based not only on morphological operations (erosion and dilation of the selected volume) but even on topological properties (connectivity, elongation, voxel count, etc...). For each ROI, several structural, morphological and textural parameters can be computed. In particular, if the ROI is composed by disconnected volumes as, for example, in the case of different spinel crystals, the connected component analysis allows to separate, label and quantify several parameters for each element. In Table 3, we listed the parameters extracted from the 3D data process and considered as the most useful for this study. In fact, the computation of these parameters is particularly suited when considering mineral phases as it will allow to define the origin of a crystal, but even understand the nature and the formation of pores and vesicles.

In the case of volumes characterized by highly interconnected features, the Dragonfly software enables to apply a skeletonization approach that allows to investigate the complexity of interconnected spaces. Throughout this analysis, we determined the number of vertices and edges of the skeletal model, deriving edges/vertices ratios, Euclidean length of edges and connectivity density of analyzed objects. The connectivity density, in particular, gives an idea of skeleton complexity and connectivity, as highly connected volumes should have very low and negative values of connectivity density. On the other hand, high positive values of connectivity density indicate volumes not connected to each other.

Parameter	Notes
<i>Voxel count</i>	Total number of voxels in each labelled object.
<i>Volume</i>	Volume occupied by each labelled object, that is, the amount of space inside of the object.
<i>Surface</i>	Is the surface area of each labelled object, that is, it refers to the outside area of the object.
<i>Volume/Surface</i>	Calculated volume-to-surface area ratio.
<i>Phi</i>	The angle from the X axis of the projection on the XZ plane of the orientation.
<i>Theta</i>	The angle from the X axis of the projection on the XY plane of the orientation.
<i>Aspect ratio</i>	Proportional relationship between the smallest eigenvalue and the largest for the inertia eigenvectors. A perfect cube or sphere would have an aspect ratio of 1.0, while a square or circle would have an aspect ratio of 0.5.
<i>Mean intensity</i>	Mean value of all voxels found for each object.
<i>Elongation</i>	Ratio of the minimum orthogonal Feret diameter to the maximum Feret diameter.
<i>Entropy</i>	Histogram-based descriptor In image processing entropy might be used to classify textures; a certain texture might have a certain entropy as certain patterns repeat themselves in approximately certain ways. A component with low entropy is more homogenous than a component with high entropy.

Table 3: Main connected components analysis parameters extracted from the 3D data processing. A more complete description of these parameters can be found at www.theobjects.com/dragonfly.

The petrographic characterization of thin sections allowed us to identify up to eight different phases: olivine, clinopyroxene, orthopyroxene, spinel, glass, sulfide, serpentine and fractures/voids. The segmentation of μ -CT data was hence performed bearing in mind the possible presence of such phases and by cross-checking the data with the results of petrography on thin sections. Given the low attenuation contrast between olivine, clino- and orthopyroxene, these minerals were

segmented as an individual phase called "silicates". Also, given the high X-ray attenuation of sulfides and their presence confirmed by thin section petrography, we segmented any phase showing gray levels higher than spinel as sulfides.

3. Results

3.1 Sample MG10x

Considering the thin section observation and following the classification of Harte (1977), Mongolian mantle xenolith MG10x (Fig.1) is a granuloblastic spinel-lherzolite. In optical microscopy observations it shows abundant three-grain junctions with $\sim 120^\circ$ between boundaries. Grain boundaries are mainly straight, sometimes curving, and there is abundant serpentine between crystals. Fluid inclusion trails are diffused inside silicates, likely reflecting entrapment of fluids during annealing of old fractures. These inclusions display various dimensions and are often multiphased in composition. Inside the larger inclusions, it is possible to recognize a small shrinkage of bubbles and opaque phases and in many cases the longer and thinner ones pinch off to form separate rounded inclusions. Many inclusions have negative-crystal shape. Olivines show the presence of kink-banding and, in one crystal, an inclusion of sub-rounded spinel. Pyroxenes have no exsolution lamellae except in one single crystal of clinopyroxene. Nearly all the clinopyroxenes display a thin spongy rim. Spinel appears as holly-leaf in shape and brown in color. Sporadically some sulfide minerals are present (Fig. 1C), usually rounded in shape, apparently associated to the alteration in serpentine but, in some cases, they are included in olivine and pyroxenes.

Tomographic data obtained at a voxel size of $30\text{ }\mu\text{m}$ (step A) show that sample MG10x has a total volume of $1.27 \cdot 10^{13}\text{ }\mu\text{m}^3$. 3D images segmentation produced three distinct phases: silicates (99.000 vol%), spinel (0.998 vol%) and sulfide (0.002 vol%). Connected component analysis shows that sulphides differ from spinels for higher mean intensity and aspect ratio (electronic supplement S1 and supplementary figure S2). Spinel forms clusters that are mostly aligned along two distinct layers (Fig. 2). Note that such layers were not detectable by observing the xenolith by the naked eye. Spinel is always vermicular in shape and apparently tends to form interconnected volumes within each layer. To quantify the possible interconnection of spinels in the layers we performed skeleton analysis on this ROI. Results summarised in Table 4.

Small sulfide grains are spread all over the analysed volume. Their distribution appears not to be associated to the spinel layering. At this resolution they appear rounded in shape.

The sub-volume analysed at a voxel size of 10 μm (step B) has a total volume of $2.46 \cdot 10^{12} \mu\text{m}^3$. It was drilled off the original sample perpendicularly to the spinel layering (see Fig.3), in order to detect possible small-scale ($< 30 \mu\text{m}$) textural or mineralogical variations associated to such a layering. Segmented phases were the same as at step A and no textural or mineralogical variations were detected. Increasing the resolution allows to better define the interconnection of spinel crystals inside layers, which is poor, as shown in Table 4 and Supplementary Figure S3. Sulphides still appear sub-rounded in shape, with volumes of the individual grains ranging from $1.30 \cdot 10^4 \mu\text{m}^3$ to $6.16 \cdot 10^6 \mu\text{m}^3$ (with more than 50% of the volumes being below $6.00 \cdot 10^5 \mu\text{m}^3$).

The sub-volume analysed at a voxel size of 2.5 μm (step C), which was in turn extracted from the sub-volume analysed at step B, has a volume of $1.13 \cdot 10^{11} \mu\text{m}^3$. At these conditions segmenting the spinel is challenging as it has a quite similar refraction index compared to the silicates. Working with segmentation in a reduced volume, avoiding the edge of the imaged sample, is useful to decrease noise. The higher spatial and contrast resolution at this step allowed to better define the shape of the sulfide grains (Fig. 4), which are sub-rounded to skeletal-like, completely amorphous or holly-leaf. In addition, it was possible to segment also serpentine (Fig.5), which occurs as low-intensity thin films, 10 to 30 μm thick, surrounding the silicates of the xenolith. This was not detectable with previous instrumental settings.

Sample	Step	Phase	Volume (mm^3)	Surface (mm^2)	Feret diameter (mm)		Edges/ Vertices ratio	Connectivity density (mm^{-3})
					Min	Max		
MG10x	A	Spinel layers	118.30	1'067.95	20.06	43.40	0.98	-2.87
MG10x	B	Spinel layers	53.17	892.56	12.40	19.11	1.05	124.23

Table 4: Skeleton analysis results summarized for spinels of sample MG10x

3.2 Sample Bi4

Based on 2D thin section petrographic observation, sample Bi4 (Fig. 6) is a protogranular spinel-lherzolite with an average grain size of 2.0 mm (Mercier & Nicholas, 1975). Grain boundaries are

mostly curving or irregular. Occasionally, three-grain junctions with $\sim 120^\circ$ are present, particularly among the smaller crystals. There are many fluid inclusion trails, usually multiphase, along fractures of both olivine and pyroxenes. Within fluid inclusions it is easy to recognize microcrystals, smaller than $15\ \mu\text{m}$ in diameter, with euhedral habitus. In many cases, smaller secondary inclusions radiate from larger ones. There are many blebs with variable size ($0.5\text{--}3.0\ \text{mm}$) and complex shape, usually associated with spinel (Figs. 6B and C). Inside these blebs, there are microcrystals of olivine, pyroxene, opaque phases and some voids, generally sub-rounded in shape. Grains in contact with blebs occasionally display on their boundary the growth of newly formed magmatic crystals.

Mineral grains clearly display evidence of deformation, particularly by the presence of strongly undulating extinction and kink banding in olivine and sporadically curved cleavage in pyroxene. Olivine displays occasionally inclusions of sub-rounded spinel. Pyroxenes have no spongy rims, and no exsolution lamellae except for one orthopyroxene and for one clinopyroxene in the whole the thin section. In addition, clinopyroxenes quite often shows some elongated elliptic and brownish inclusions. Spinel forms holly-leaf crystals and is always associated with microcrystalline blebs, except for the tiny subhedral spinel included in olivine or located at the junction between silicates. Unidentifiable opaque phases are present within blebs and occasionally as interstitial phases.

Tomographic data acquired at a voxel size of $21\ \mu\text{m}$ (step A) show that sample Bi4 has a total volume of $3.43 \cdot 10^{12}\ \mu\text{m}^3$. Segmentation produced three distinct phases (Fig. 7): silicates (97.900 vol%), spinel (1.491 vol%), high-density phases (HDP; 0.017 vol%) and voids (0.592 vol%). Connected components analysis for high intensity volumes (spinel and HDP) and voids are given in electronic supplement S1. As underlined for sample MG10x, statistical analyses allow to discriminate between spinel and HDP, as shown in supplementary figure S4. Spinel is arranged both in small anhedral crystalline aggregates with individual volumes ranging from $9.26 \cdot 10^3\ \mu\text{m}^3$ to $2.00 \cdot 10^9\ \mu\text{m}^3$ and bigger vermicular clusters (Fig. 7A) with volumes ranging from $5.73 \cdot 10^9\ \mu\text{m}^3$ to $1.76 \cdot 10^{10}\ \mu\text{m}^3$. High-density phases are rounded and smaller with respect to spinel and appear to be spread all over the xenolith, with a particular concentration along a surface at the top of the xenolith (the contact between xenolith and host basalt; Fig. 7B). Interestingly, the xenolith shows a considerable volume of voids, sub-rounded in shape, that appear to be concentrated on the surface of the large spinel clusters (Fig. 7A). The $\mu\text{-CT}$ images allowed to clearly detect even several fractures (from 90 to $350\ \mu\text{m}$ in width), particularly a large one cutting the xenolith in half.

The analysis of $\mu\text{-CT}$ data corresponding to a voxel size of $6.25\ \mu\text{m}$ (step B) focused on the upper portion of xenolith Bi4 (Fig. 8), having a total volume of $2.54 \cdot 10^{11}\ \mu\text{m}^3$. Segmented phases are the

same as in step A. Spinel form a large cluster of $1.16 \cdot 10^{10} \mu\text{m}^3$, several crystals of intermediate dimensions and many smaller (average volume of $1.00 \cdot 10^9 \mu\text{m}^3$). Spinel is always surrounded by what appears as blebs of small neoblasts euhedral in shape, with low-density material in between. The large spinel cluster displays the presence of several inclusions with low brightness (see the slice in Fig. 8A) that are not in contact with the surface of the spinel, which suggest they might be primary melt inclusions. Larger ones seem to be composed by the same aggregate composing the blebs, while smaller are usually glassy inclusion sometimes with a gas bubble inside. Voids are arranged in three different ways: surrounding the large spinel cluster, dispersed around the small spinel crystals and aligned along the surfaces, hinting the existence of several possible fractures. Some voids appear isolated (0.66 vol%, considering the sub-volume in step B) while other appear interconnected and connected with the limits of our imaged sample (35.2 vol%).

The sub-volume analysed at step C ($6.07 \cdot 10^{10} \mu\text{m}^3$; voxel size: $2.5 \mu\text{m}$; Fig. 9) has been extracted from the sub-volume analysed at step B. It shows approximately $2.20 \cdot 10^9 \mu\text{m}^3$ of spinel, which was manually segmented for the same reason as in xenolith MG10x. High-density materials occupy a volume of $7.00 \cdot 10^7 \mu\text{m}^3$ and, at this resolution, it was possible to better define their texture. Larger volumes are the ones present at the top of the sample (Fig. 9B), aligned with the surface at the edge of the xenolith; there are then several small, rounded crystals scattered inside what clearly appear as blebs of silicate neoblasts surrounding spinel. There are also some small anhedral and elongated phases inside fractures (Fig. 9A), these are the brightest when considering the absorption of what we call high-density material (see also Fig. 10). Fractures are visible inside all the analysed volume and are sometimes connected with the blebs surrounding spinel. The material composing blebs and filling the fractures seems to be the same (Fig. 10), with the difference that larger euhedral neoblast are preferentially inside blebs, which are wider. The area between neoblasts is filled by voids and by a low-density material, similar in adsorption with respect to silicates (it was not possible to segment it at the current stage) which is even the main phase present inside fractures. Voids are therefore present both in blebs surrounding spinel and in fractures, showing always a sub-rounded bubble-like shape. The total volume of voids inside the analysed sample is $3.96 \cdot 10^9 \mu\text{m}^3$ and they are all isolated with respect to the edges of the xenolith. That means void bubbles are not connected to each other nor to the exterior of the xenolith. The top of the xenolith was imaged even at a higher resolution, with a voxel size of $0.9 \mu\text{m}$ (step D), to better characterize the high-density material that here appears as more concentrated (Fig. 11).

3.2 Sample FN38

Optical microscopy observations allow us to define sample FN38 (Fig. 12) as protogranular lherzolite with some large crystals of olivine. Grain boundaries are mainly irregular, sporadically straight and showing some triple junctions. Olivine has kink-bands, particularly in the larger crystals, while clinopyroxene has a spongy texture. The main characteristic of this xenolith is the presence of extended patches, embedded in the coarse matrix, made by glass and subequal neoblasts crystallized inside (Fig. 12B and C). Inside these patches there are some vesicles filled with zeolites. In the thin section, spinel is always inside these patches, forming small euhedral crystals. There are even some smaller glassy pockets, preferentially developed at the junction of grains. Neoblasts in the glassy patches display quite often a clear euhedral shape. These are mainly olivine, always in small euhedral crystals, clinopyroxene, commonly in spongy aggregates, euhedral spinel crystals and rarely plagioclase, in one case showing zoning. The bigger patches show very few glasses and have olivine porphyroclasts inside, which are irregular in shape and display no reaction rim. On the contrary, smaller patches are characterized by the absence of porphyroclasts and by the presence of abundant glass.

Considering the computed microtomography, step A was carried out with a voxel size of $23.3\ \mu\text{m}$ (Fig. 13); the total analysed volume is $6.02 \cdot 10^{12}\ \mu\text{m}^3$. Segmented phases are silicates (98.500 vol%), glass (1.494 vol%) and spinel (0.006 vol%). Connected components analysis of glasses and spinels are given in electronic supplement S1. Spinel shows a higher absorption with respect to the MG10x and Bi4 spinel and is arranged in small ($1.64 \cdot 10^7\ \mu\text{m}^3$) crystals aggregates, with no evidence of large clusters as in Bi4. The glass phase, which is characterized by a higher absorption than air and lower than silicates, is abundant, not only in concomitance with spinel, but always surrounding the spinel. Glass forms either small, isolated patches or elongated pockets, sometimes interconnected among them and in contact with the surface of the analysed volume (note that this does not correspond to the contact between xenolith and host lava). At this spatial resolution, half of the total glass volume (0.756 vol%) appear as pockets that are isolated from the surface of the investigated sample. To better define the interconnectivity of the glass we performed skeleton analysis on this ROI. Results show high interconnectivity and are summarized in table 5 and in supplementary figure S5.

Step B (voxel size: $6.7\ \mu\text{m}$) focused on the central part of sample FN38, analysing a total volume of $8.00 \cdot 10^{11}\ \mu\text{m}^3$. Segmented phases are the same as in step A (Fig. 14). No further textural details were noted for spinel (see the slice in Fig. 14A). Also, at this spatial resolution, a portion of the glass

(1.005 vol%, relative to total volume of the sample) appear not connected to the edges of the analysed volume.

Step C focused on the inner part of the volume analysed at step B, imaging a total volume of $9.64 \cdot 10^{10} \mu\text{m}^3$. The main improvement here is the possibility to see the microlites of spinel inside the glassy patches (Fig.15) and some vesicles filled with a material similar in density to the silicic glass (possibly zeolites), which were undetectable at lower resolutions and visible only in the thin section. A selected volume of interest was imaged with a voxel size of $0.9 \mu\text{m}$ (step D). Here it was possible to better characterize the low-density volumes. In fact, there are not only glass patches but also tiny films of glass occupying the intercrystalline space (Fig. 16).

Sample	Step	Phase	Volume (mm ³)	Surface (mm ²)	Ferret diameter (mm)		Edges/ Vertices ratio	Connectivity density (mm ⁻³)
					Min	Max		
FN38	A	Glass	91.19	2'071.96	16.25	52.62	0.92	-72.30
FN38	B	Glass	8.04	781.08	8.33	15.10	0.95	-3499.27

Table 5: Skeleton analysis results summarized for glasses of sample FN38.

4 Discussions

As we introduced in the geological setting section, our samples have in common the type of magmatism that brought to the surface these xenoliths. All come from an OIB like alkaline intraplate magmatism, Mongolian (MG10x) and Moroccan (Bi4) a continental one, while Fernando de Noronha's sample (FN38) from a real OIB. What changes from a locality to the other is the geodynamic, as the Mongolian xenolith represents a piece of lithosphere in a mobile belt zone, Bi4 a xenolith from a pericratonic area while FN38 comes from the upper mantle beneath oceanic crust. This imply that the depth of sampling varies for the three xenoliths.

4.1 Spinel morphology

In mantle xenoliths, spinel can occur with various morphologies, from vermicular to skeletal or even euhedral crystals (Matsumoto and Arai, 2001). According to Mercier and Nicolas (1975), in protogranular peridotites spinels are considered as an exsolution product from enstatite. They recrystallized to an interstitial or mosaic shape. In xenoliths with a porphyroclastic texture, which are considered as the product of deformation of protogranular peridotites, spinel recrystallizes to elongated holly-leaf shaped grains. In equigranular textures, polygonal spinels may occur between the other crystals. Nielson Pike and Schwarzman (1977) considered the presence of euhedral spinel in or between silicates as indicative of a so-called igneous xenolith.

Pyrometamorphic textures are caused by the solidification of local partial melts within the rocks. Here, tiny quench crystals of euhedral oxides can be found (Nielson Pike and Schwarzman, 1977). In xenoliths that have undergone limited recrystallization or are in early stages of polygonization, spinels are small, disseminated, forming holly-leaf interstitial grains due to the fact that silicates are reduced in size by polygonization and mechanical breakdown (Nielson Pike and Schwarzman, 1977). In foliated and equigranular mosaic textures, spinel is interstitial in clumps or strings parallel to the foliation (Nielson Pike and Schwarzman, 1977). Samples MG10x and Bi4 show anhedral spinel (Fig. 1B and 6C), which are termed holly leaf (Mercier, 1975) and is characterized by the presence of appendices directed inside the silicate matrix surrounding the spinel.

Our μ -CT results show how morphology and texture of spinel grains is fully understandable only through a 3D reconstruction. Consider for example the thin section of sample Bi4 (Fig. 6) where spinel appears with a classical holly leaf shape, it is surrounded by microcrystalline blebs and show no visible inclusions. μ -CT shows that in this sample the spinel is present in two main forms (Fig. 7): big clusters with high surface/volume ratios and small sub-rounded crystals. The first case is always surrounded by voids, while it is difficult to evaluate if the same is true for the second spinel occurrence. Furthermore, at higher resolution (step B and following, Fig. 8 and 9) the large spinel cluster appears rich in several inclusions, which were not detected in the thin section under the optical microscope. These inclusions appear always rounded in shape and apparently filled with the same phases present in the bleb that surround the spinel (see chapter 4.4).

In sample FN38 the 3D model underlined the presence of aggregates of spinel crystals that in the thin section can be confused as whole spinel grains. Furthermore, the spinel of FN38 is highly absorbing with respect to the one of the other two xenoliths, which probably reflect different compositions. In sample FN38 there is no holly-leaf spinel with high surface/volume ratios, and the

few crystals present appear as formed by aggregates of smaller ones (Fig.13), with high absorbance. Increasing the resolution to 2.5 μm of voxel size (step C, Fig. 15), it is possible to notice another kind of spinel, scattered in the glass and smaller in size. This is the spinel we observed in thin section, crystallized inside glassy patches.

For this textural feature however, the resolution of the $\mu\text{-CT}$ analysis plays a fundamental role, as at voxel sizes higher than 6.25 μm for sample Bi4 and 2.5 μm for the xenolith FN38 the texture of spinel was not fully characterizable.

4.2 Spinel layering

Spinel layering has been investigated in sample MG10x and it is a clear example of how a traditional thin section may hampers an appropriate interpretation of the xenolith. The bigger problem seems to be the randomly sectioning plane of a thin section, and even through a targeted thin section, as the one we physically made (Fig.1), it is difficult (if not impossible) to find all the information that are instead clearly evident with the 3D model obtained with computed microtomography. We discussed extensively the problem in the further consideration section, giving some quantitative data about random sectioning of a sample.

Looking at the thin section, the presence of a spinel layering is poorly understandable even through a targeted section, but it appears clear when looking at the 3D model obtained with $\mu\text{-CT}$. As a matter of fact, since step A it was possible to recognize at least two different spinel layers crossing the sample and suggesting a fragile zone as the source of this mantle xenolith. As a result of tectonic stress, the mantle experienced some shear zones where fluids may percolate leading to the crystallization of spinel, which had all the time to form, grow and stabilize itself.

Moreover, considering optical microscopy observations, spinel appears as classical mantle spinel with holly-leaf texture. Even its absorption in the $\mu\text{-CT}$ slices suggest a composition similar to that of restitic spinel, as in sample Bi4. However, given its arrangement in layers, it is more appropriate to classify this kind of spinel as magmatic, crystallized directly from a melt that percolated the mantle. This kind of layering is already discussed in literature, for both spinel and other mineral phases; consider for example the Balmuccia peridotite showing massive monomineralic spinel layers 10 cm thick (Mazzucchelli et al., 2009), or the websteritic veins in the Lherz Massif (Le Roux et al., 2007). However, it is difficult to find studies about small-scale layering as the one we are here discussing, thus although the processes may be the same new studies would be necessary.

Considering how tough is to identify this textural feature in thin section observation, it is very likely that it could be missed many times.

Note that these textural interpretations were possible only through to the 3D model obtained by μ -CT analysis. With this xenolith, which shows a homogeneous coarse-grained texture, even a low-resolution imaging (step A) may be sufficient to a first textural 3D study.

4.3 Sulfides

In samples MG10x and Bi4 there are some phases with higher attenuation with respect to the spinel grains that on the base of optical microscopy observations have been identified as sulphides. According to literature, their presence can be correlated to texture of mantle xenoliths. Szabó and Bodnar (1995), for example, indicate that the distribution of sulfides in upper mantle is linked to deformation and recrystallization processes, therefore a 3D analysis may be fundamental in understanding texture and distribution of sulfides. Some authors, as Wang et al. (2020), tentatively described in three dimensions the mechanism that led to the formation of sulfides inside partially molted peridotite, but they worked with synthetic samples. So up to now no studies on 3D distribution and morphology of sulfides inside natural mantle xenolith exist, to our knowledge.

In the Mongolian sample, sulphides are homogeneously disseminated into the xenolith, with no apparent spatial relationships with the spinel layering. This is confirmed by phi and theta values in the connected component analysis (see electronic supplement S1), as these variables indicate the orientation of the segmented volumes, similar values means a similar orientation (a tabular texture for example), different values mean scattered volumes. Because of the small size and very low abundance of sulphides, this feature cannot be noticed in the thin section. Moreover, modelling with accuracy the morphology of these sulfides was possible only through synchrotron radiation-based tomography, as testified by Fig.4. The crystallization of sulfides is not concomitant with the formation of the spinel or, however, independent from the event that led to the crystallization of spinel. We speculate, considering the distribution of these high-density sulfides, that the percolation of small volume melts in inter-grain spaces may be responsible for their deposition (Wang et al., 2020 and reference therein).

Regarding sample Bi4, there are high density volumes clearly visible in step A and B, which appear as randomly scattered inside the volume and not affected by the presence of spinel clusters. At 2.5 μm of voxel size, it is possible to recognize how high-density phases are present only in the

percolating melt, sometimes even in the blebs surrounding spinel but preferentially inside fractures. This may suggest an in situ sulfide liquid immiscibility that led to the precipitation of this kind of elongated sulphur in melt filled cracks (Fig.9A and 10) as proposed by Lorand (1991). We focused a scan with the higher resolution of 0.9 micron (step D, Fig.11) on the top of our sample, discovering this was probably a fracture where the xenolith broke. Here we have the bigger volumes with high-density and they appear particularly similar to SEM backscatter electron images of sulfide (Hughes et al., 2016).

4.4 Glass, voids, fractures

Glasses in xenoliths may represent reaction products between mantle xenoliths and migrating small volume melts percolating the mantle, which contribute to mantle heterogeneity and metasomatism (Coltorti et al., 2000; Fialin et al., 2011; Miller et al, 2012; Lahmer, 2018; and reference therein). Despite the importance of such phenomena the 3D distribution of glasses and relative gas vesicles inside xenoliths is not studied yet, except for the preliminary work by Patkó et al. (2020).

The Moroccan sample Bi4 shows the presence of microcrystalline blebs around spinel in thin section, that seem to be not connected among them, sometimes showing a glassy film between phases. μ -CT data show no evidence of these blebs using a resolution of 21 μm (step A), probably because of the similar densities of the different silicates composing blebs, which result in small phase contrast in the acquired data. What is clear from observing this 3D model (Fig.7) is the presence of several voids and some fractures. Increasing the resolution to 6.25 and 2.5 μm (steps B and C) was fundamental for this sample. First, the blebs surrounding spinel, which are not visible at a lower resolution, appear at 6.25 μm and are even clearer at 2.5 μm . Second, some of the microcrystalline blebs are present also inside larger spinel crystals and show no connections to their exteriors. There are even inclusions characterized by the presence of only glass and gas bubbles, still preserved inside the crystal. This is another example of the advantages of computed microtomography, i.e., it is possible to clearly identify inclusions and verify whether they are connected with the exterior of the host crystal. In the case of our sample, these observations might indicate that the spinels crystallized from the melts that are now represented by the multi-phase blebs. A combination of these data with chemical analyses is needed to confirm such a hypothesis and would provide new constraints on the formations of spinels in mantle peridotites.

Another feature that needs to be revisited after analysis at higher resolution are fractures. As at 6.25 micron of voxel size every fracture may be well characterized, it is possible to notice that they are fulfilled with the same material forming the blebs around spinel. This evidence underlines how blebs are not isolated but connected with fractures and thus the formation of blebs may be related to the percolation of melts inside the xenolith, which is probably driven by the prior formation of fractures. Moreover, this melt solidified at a pressure sufficiently low to allow degassing, as testified by the presence of several vesicles. Voids are always sub-rounded in shape and present in blebs as in fractures (see Fig.9 and 10).

Considering the thin section of mantle xenolith FN38, it is immediately clear that the sample has one main particularity: the presence of glassy patches all around, with neoblasts crystallizing inside and some voids now fulfilled by zeolites. This is an evidence of melts percolating the mantle, though it is unclear considering the two-dimensional section if the glassy patches are isolated or represent channels extending through the xenolith. Looking at the three-dimensional model, obtained with computed tomography at 23.33 μm of voxel size (Fig.13), it is possible to notice that glass is scattered all around the sample and, differently respect to the blebs of sample Bi4, its presence seems to be independent from the spinel. Interconnection may be even more evident considering connectivity density in the skeleton analysis (table 5); this allows us to confirm this melt is not (or not only) the product of partial melting of some crystals but represent a liquid phase that permeated the xenolith. As a matter of fact, when considering smaller voxel sizes, such as 6.7 μm , the connection between glassy patches appear clearer and thus volumetric considerations more robust. Considering all the resolutions we used in the acquisition of μ -CT scans, glassy patches appear as largely diffused and highly interconnected (through both large channels and small intergrains spaces), testifying melts that were percolating extensively in the mantle section sampled by the xenoliths.

4.5 Modal proportions of spinel

It is common use in petrography to estimate the volumetric percentage of a mineral over a 3D sample by using point counting or image analyses on a single 2D thin section. However, if the sample is anisotropic, applying this procedure to sections that have been randomly cut from the sample

may add unknown errors in the estimate. In order to quantitatively evaluate such errors, we simulated the acquisition of several 2D slices: this allows us to compare the areal percentage estimated from each 2D thin sections with the actual value calculated from the entire volume.

We started from the labelled 3D model obtained with the lower resolutions (step A) and we took 50,000 random slices over the three axis. To better simulate the real slicing process, this random process has the only constrain that the obtained slice must have an area at least equal to the slice taken orthogonal to the longest axis. This constrain is introduced to avoid the algorithm to take into account unrealistic slices, e.g. a thin section that takes only a small portion of the whole sample.

By doing this, we can simulate the estimation of the percentage of spinel that would be done from each 2D thin section. Results can be seen in Fig.17, for the three studied xenoliths.

Assuming a normal distribution of the samples we fit the estimated volumetric percentage of spinel with:

$$f(x) = \alpha * e^{-\left(\frac{(x-\mu)}{2\sigma^2}\right)^2}$$

Where α is $\frac{1}{\sqrt{2\pi\sigma^2}}$, μ is the mean value and σ is the standard deviation (std).

In Table 6 the parameter of gaussian fit of the distribution are presented.

Sample	Real Mean	μ	σ	R-squared
MG10x	0.9265	0.8663	0.5199	0.9912
Bi4	1.4143	0.9543	1.653	0.99
FN38	0.0298	-	-	-

Table 6: Resuming data of the thin section simulation and relative parameters.

Sample MG10X present a distribution centred in 0.8663 with a standard deviation of 0.5199: there are outliers in the range [2.0% - 3.0%] that may be due to the layered distribution of spinel in the sample.

Sample Bi4 shows a trend similar to MG10x, but it has a higher range of variability with a mean of 0.9543 with a std of 1.653. The higher std should be due to the cluster distribution of spinel, which increase the probability of a wrong identification of the right value.

While MG10X and Bi4 fits well a Gaussian distribution, FN38 does not: this may be due to the very low quantity of the mineral in the sample and its uniform distribution.

According to the well-known empirical rule (Pukelsheim, 1994):

$$Pr(\mu - 1\sigma \leq X \leq \mu + 1\sigma) \approx 68.27\%$$

In the mantle xenolith MG10x, with μ of 0.8663 and a σ of 0.5199 (refer to Table 6 for further details), there is a probability of 68.27% to estimate a spinel percentage between 0.3464% and 1.3862%. The estimated value within 2σ , that should correspond to 95.45% of probability, should lay between 0.0% and 1.9061%.

5. Conclusions

In this study, we applied multi-modal X-ray microtomographic imaging to characterize at different scales the texture properties of several mantle xenoliths coming from different geodynamic settings. The extracted volumetric models allow us to well define the texture of our samples with a completeness and detail not comparable to classical thin sections analysis. The multi-scale approach applied to a variety of textures allowed to pinpoint a series of recommendations for future petrological studies of mantle xenoliths through X-ray micro-CT:

- If the goal of the study is to verify possible spinel layering, low resolution X-ray μ -CT (as our step A) can be sufficient and will allow to characterize the whole xenoliths, which typically have size in the range 1–10 cm .
- Characterizing spinel morphology and internal texture requires high resolution, as the ones we reached in steps C and D. This allows also to identify possible inclusions, which are important for the interpretation of spinel crystallization environment. The low resolution of step A and B may lead to mistakes as testified by the small spinel crystals of FN38, visible only at 2.5 and 0.9 μm of voxel size.
- Presence, distribution and texture of sulfides. The presence of such phases was verified through thin section observation, but the modal abundance, distribution and texture was quantified only through micro-CT. In the volumetric analysis the distribution of high-density minerals is easy to achieve even at low resolutions (step A), thanks to their high attenuation coefficient. For the texture, instead, because of the small size of these phases and the high absorbance they have, to characterize properly the shape it is necessary a small voxel size (steps C and D). As shown in Fig.4 and Fig.11 we obtained the best results with a voxel size of 2.5 μm for sample MG10x and 0.9 μm for sample Bi4. Moreover, considering the very low abundance of sulfides and platinoids inside mantle samples, it is worth noting that with a proper 3D reconstruction it will be then easy to target with high precision where to cut the sample for further chemical analysis.

- Voids and their morphology. In the thin section, voids are clearly visible inside microcrystalline blebs and their sub-rounded shape is identifiable. However, only through 3D reconstruction at high resolution (e.g., our steps C and D) it is possible to detect and quantify the presence of such void inside the fractures of the xenolith, along with the glass that originated them.

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Figure captions

- Figure 1: A) Thin section of mantle xenolith MG10x in plane polarized light; B) detail of a spinel cluster; C) sulfide crystal included in olivine.
- Figure 2: 3D reconstruction of sample MG10x obtained at step A (see text and Table 1), 1147x921x1796 voxels. Spinel segmented in orange and sulfides in green.
- Figure 3: 3D reconstruction of a volume of interest in sample MG10x obtained at step B (see text and Table 1), 2004x1536x1240 voxels. Analyses were carried out at TomoLab with a voxel size of 10 micron. Spinel segmented in orange, sulfides in green.
- Figure 4: 3D reconstruction of a volume of interest in sample MG10x obtained at step C (see text and Table 1), 1585x1453x3322 voxels and zooms on some sulfide grains segmented in green.
- Figure 5: 3D reconstruction of a volume of interest in sample MG10x obtained at step C (see text and Table 1), 1585x1453x3322 voxels. The red phase is serpentine, which fills fractures and intergranular spaces.
- Figure 6: Thin section (A) of sample Bi4 and optical microscope images in plane polarized light. B) and C): notice the microcrystalline bleb surrounding spinel.
- Figure 7: 3D reconstruction of mantle xenolith Bi4 obtained at step A (see text and Table 1), 726x660x1969 voxels. Spinel segmented in orange, voids in blue and high-density phases in green. A) Detail of a spinel cluster. B) Detail of the high-density phase alignment at the top of the sample; for the sake of clarity, spinels and voids have been removed from this inset.

Figure 8: 3D reconstruction of a volume of interest in mantle xenolith Bi4 obtained at step B (see text and Table 1), 1519x1058x1245 voxels. Spinel segmented in orange, voids in blue and high-density phases in green. A) one of the slices composing the 3D model.

Figure 9: 3D reconstruction of a volume of interest in mantle xenolith Bi4 obtained at step C (see text and Table 1), 1833x1949x1852 voxels. Spinel segmented in orange, voids in blue and high-density phases in green. A) Detail of voids and high-density phases crystallized inside fractures. B) Detail of the high-density phases at the top of our sample.

Figure 10: One of the slices composing the 3D model of Fig.9. Arrow indicating a high-density phase crystallized inside a fracture (see Fig.9A). Circle highlighting a microcrystalline bleb surrounding spinel (Sp).

Figure 11: 3D reconstruction of a volume of interest in mantle xenolith Bi4 obtained at step D (see text and Table 1), 1865x1865x2048 voxels. High-density phases segmented in green.

Figure 12: Thin section of mantle xenolith FN38 (A) and details of glassy patches with neoblasts crystallized inside (B and C) in plane polarized light.

Figure 13: 3D reconstruction of mantle xenolith FN38 obtained at step A (see text and Table 1), 1121x764x2151 voxels. Spinel segmented in orange, glass in blue.

Figure 14: 3D reconstruction of a volume of interest in mantle xenolith FN38 obtained at step B (see text and Table 1), 1970x1700x1256 voxels. Spinel segmented in orange, glass in blue. A) One of the slices composing the 3D model; notice the absence of spinel (white) inside glassy patches (dark grey).

Figure 15: 3D reconstruction of a volume of interest (A) in mantle xenolith FN38 obtained at step C (see text and Table 1), 1953x1705x1852 voxels. Spinel segmented in orange. Notice the presence of larger spinel crystals and smaller spinel neoblasts.

Figure 16: 3D reconstruction of a volume of interest (A) in mantle xenolith FN38 obtained at step D (see text and Table 1), 1825x1833x2048 voxels. Spinel segmented in orange, glass in blue. Arrows pointing at glass filling the intergrain space.

Figure 17: Results of the simulation on 50000 random sections taken in the 3D models of the xenoliths obtained via ICTP data (steps A in Table1), and relative fit.

Supplementary Figure S2: Graph showing Mean intensity vs. Aspect ratio for the high intensity volumes segmented from the three xenoliths. Data obtained through connected components analysis at step A (see electronic supplement S1).

Supplementary Figure S3: 3D model obtained at step B for mantle xenolith MG10x. Silicates in light grey, spinel in light orange. Skeleton analysis is visible inside spinel, with colour spectrum ranging from blue (lowest connectivity) to red (highest connectivity). Radius of vertices reflecting their connectivity and edge radius reflecting Euclidean length of edges.

Supplementary Figure S4: 3D model obtained at step A for mantle xenolith Bi4. Silicates in light grey. Here the subdivision of high intensity ROI into: A) low Volume/Surface ratio (in yellow); B) high volume/surface ratio (in black). Notice how yellow highlighted volumes match spinel of Fig.7.

Supplementary Figure S5: A) 3D model obtained at step A for mantle xenolith FN38. Glass in light blue, silicates in light grey. B) inset showing skeleton analysis inside glasses, with colour spectrum ranging from blue (lowest connectivity) to red (highest connectivity). Radius of vertices reflecting their connectivity and edge radius reflecting Euclidean length of edges.

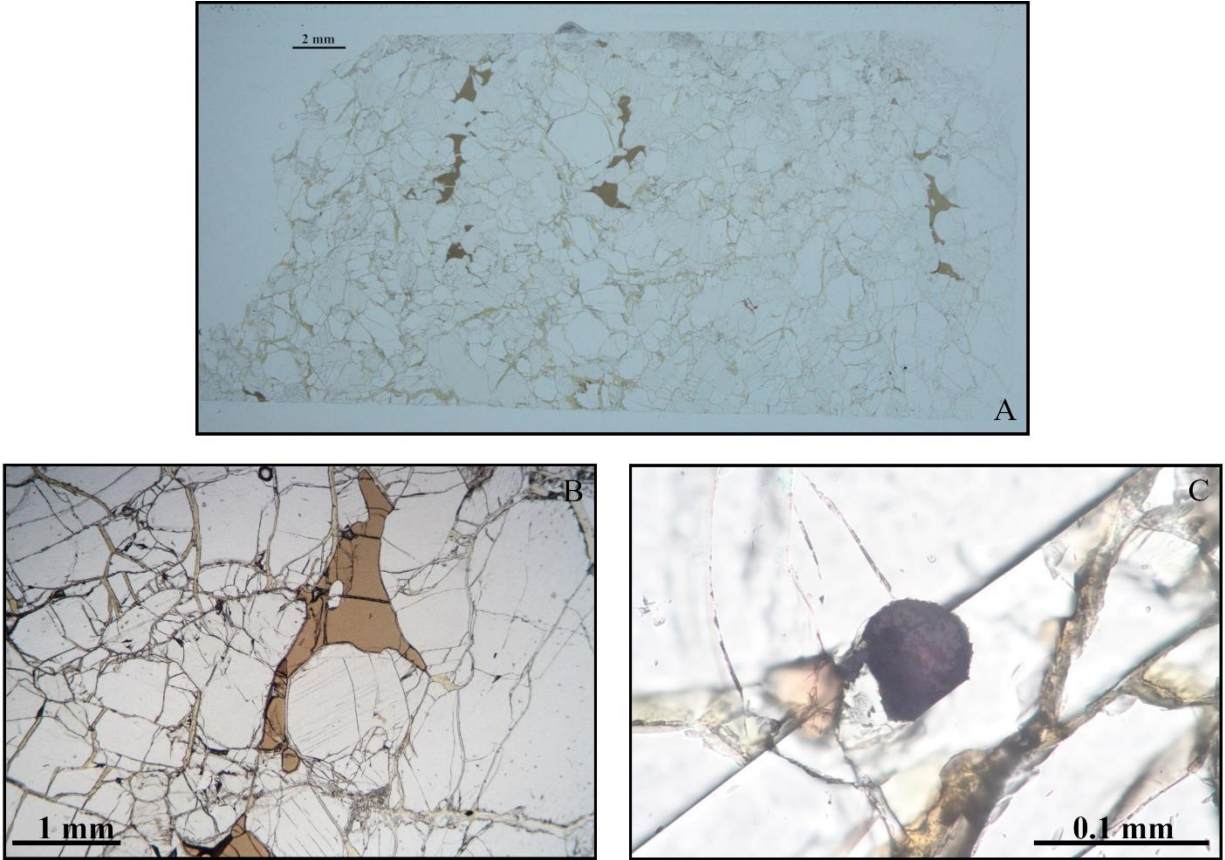


Figure 1: A) Thin section of mantle xenolith MG10x in plane polarized light; B) detail of a spinel cluster; C) sulfide crystal included in olivine.

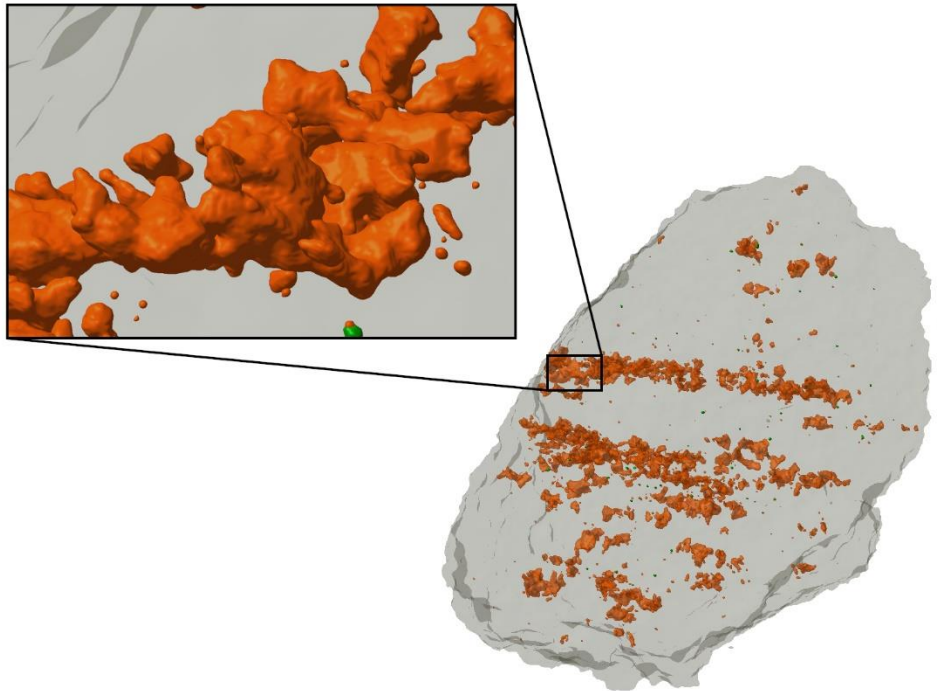


Figure 2: 3D reconstruction of sample MG10x obtained at step A (see text and Table 1), 1147x921x1796 voxels. Spinel segmented in orange and sulfides in green.

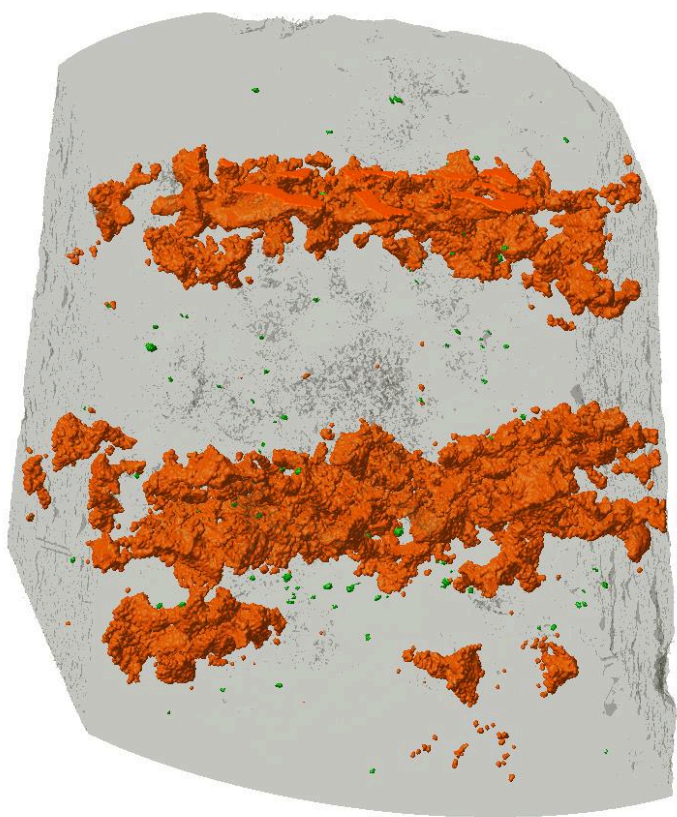


Figure 3: 3D reconstruction of a volume of interest in sample MG10x obtained at step B (see text and Table 1), 2004x1536x1240 voxels. Analyses were carried out at TomoLab with a voxel size of 10 micron. Spinel segmented in orange, sulfides in green.

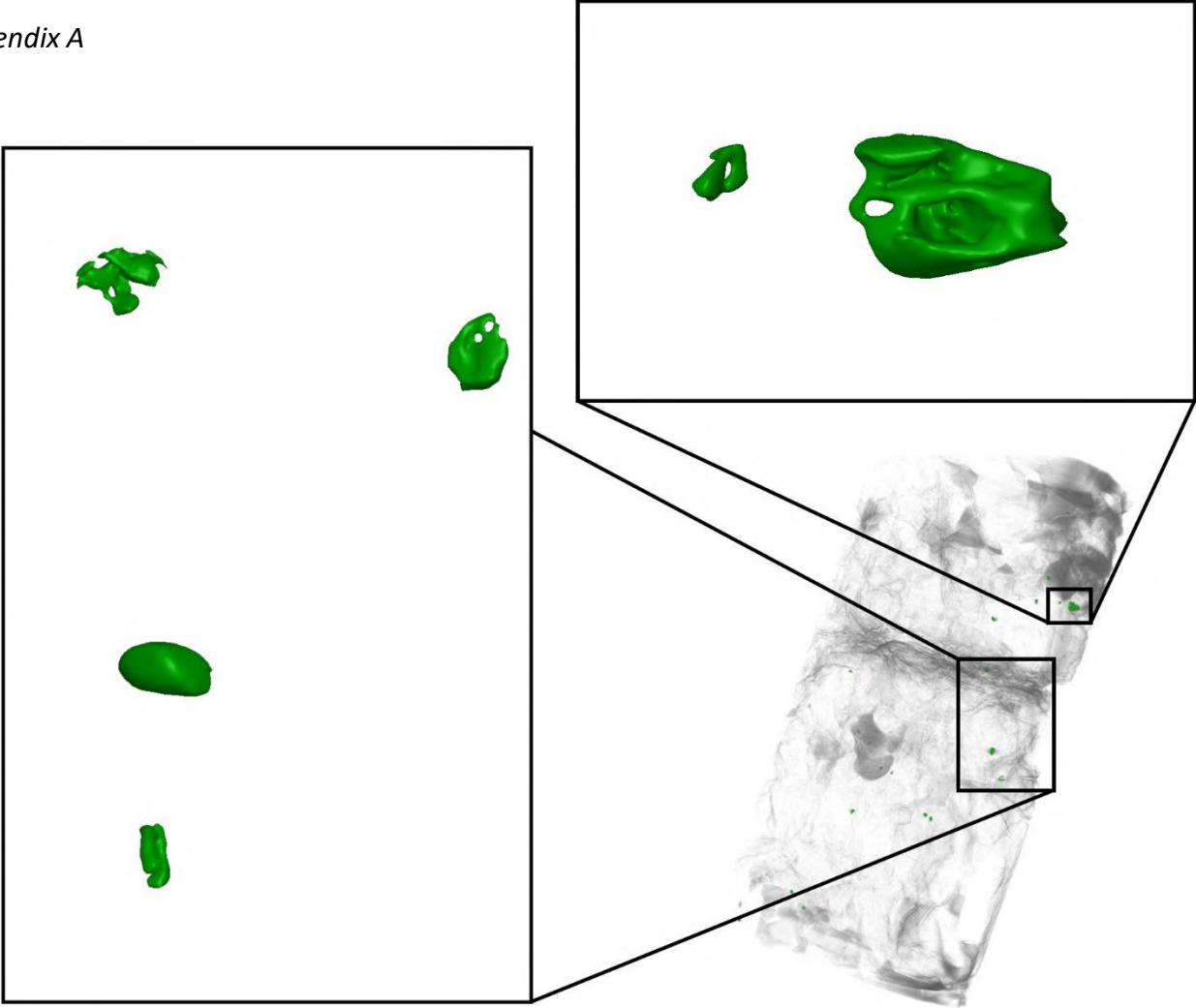


Figure 4: 3D reconstruction of a volume of interest in sample MG10x obtained at step C (see text and Table 1), 1585x1453x3322 voxels and zooms on some sulfide grains segmented in green.



Figure 5: 3D reconstruction of a volume of interest in sample MG10x obtained at step C (see text and Table 1), 1585x1453x3322 voxels. The red phase is serpentine, which fills fractures and intergranular spaces.

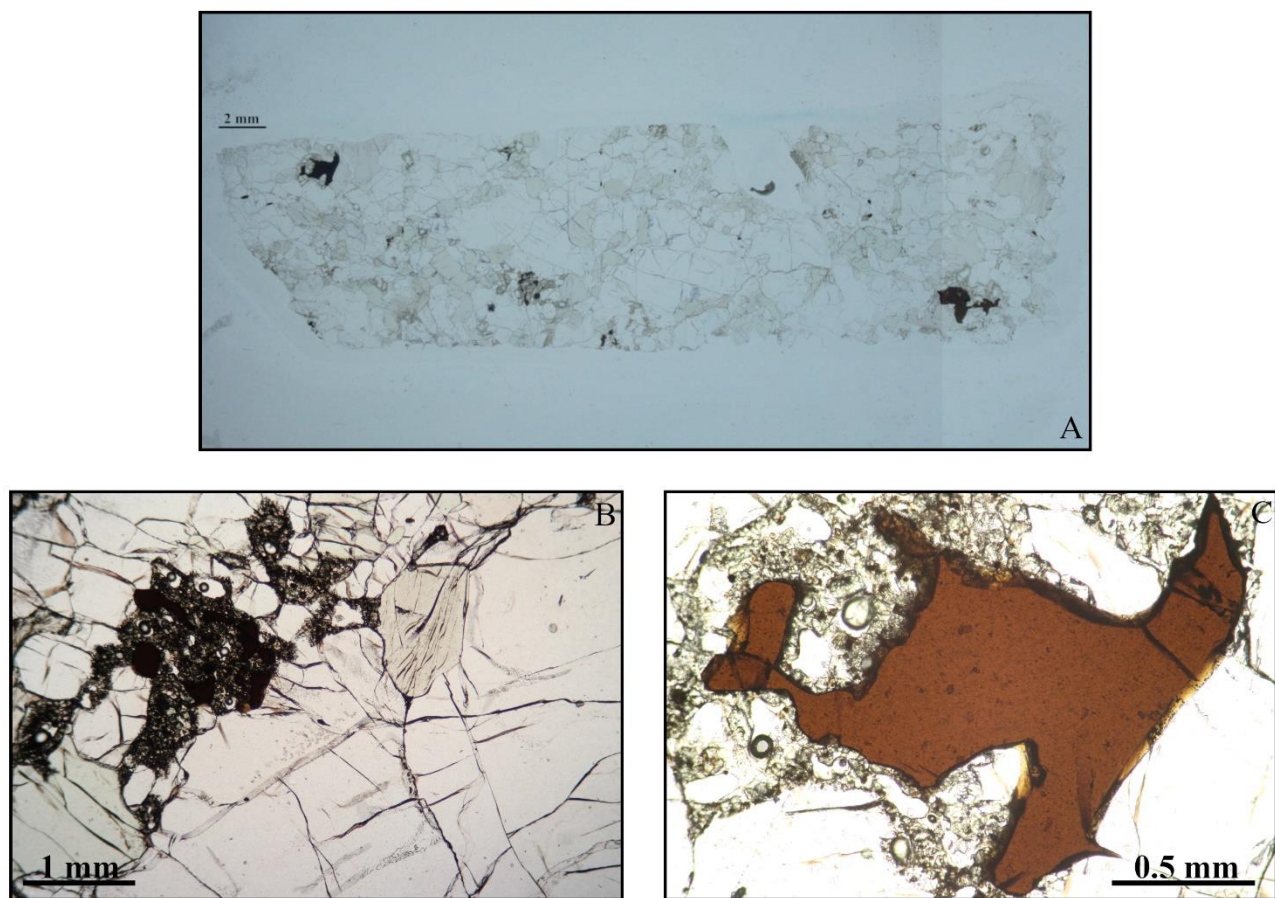


Figure 6: Thin section (A) of sample Bi4 and optical microscope images in plane polarized light. B) and C): notice the microcrystalline bleb surrounding spinel.

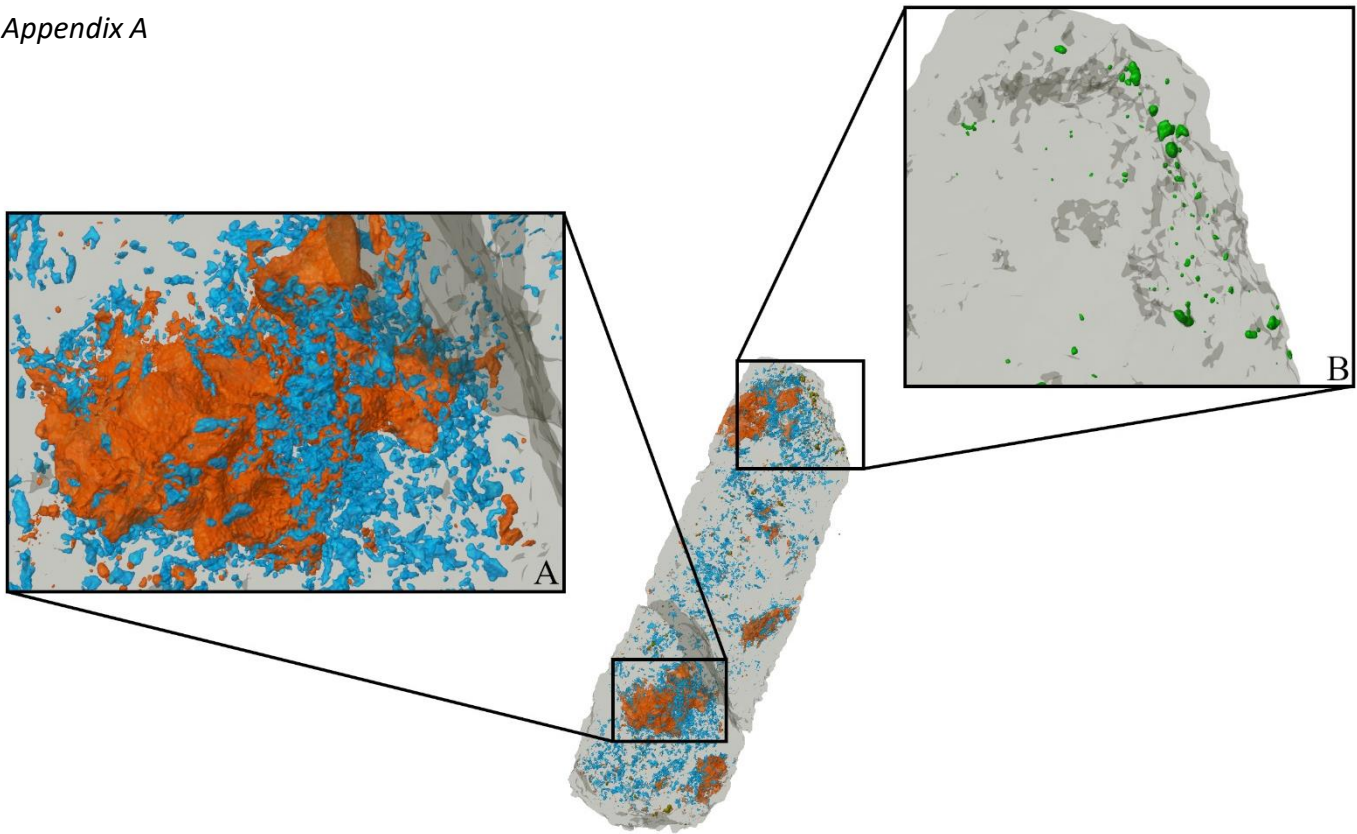


Figure 7: 3D reconstruction of mantle xenolith Bi4 obtained at step A (see text and Table 1), 726x660x1969 voxels. Spinel segmented in orange, voids in blue and high-density phases in green. A) Detail of a spinel cluster. B) Detail of the high-density alignment at the top of the sample; for the sake of clarity, spinels and voids have been removed from this inset.

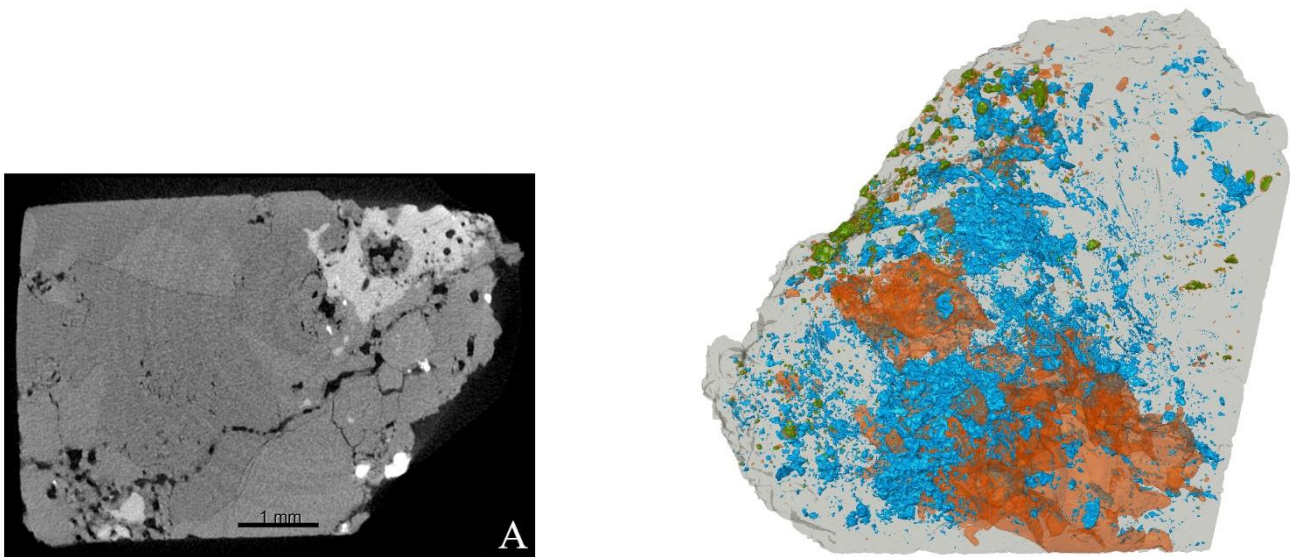


Figure 8: 3D reconstruction of a volume of interest in mantle xenolith Bi4 obtained at step B (see text and Table 1), 1519x1058x1245 voxels. Spinel segmented in orange, voids in blue and high-density phases in green. A) one of the slices composing the 3D model.

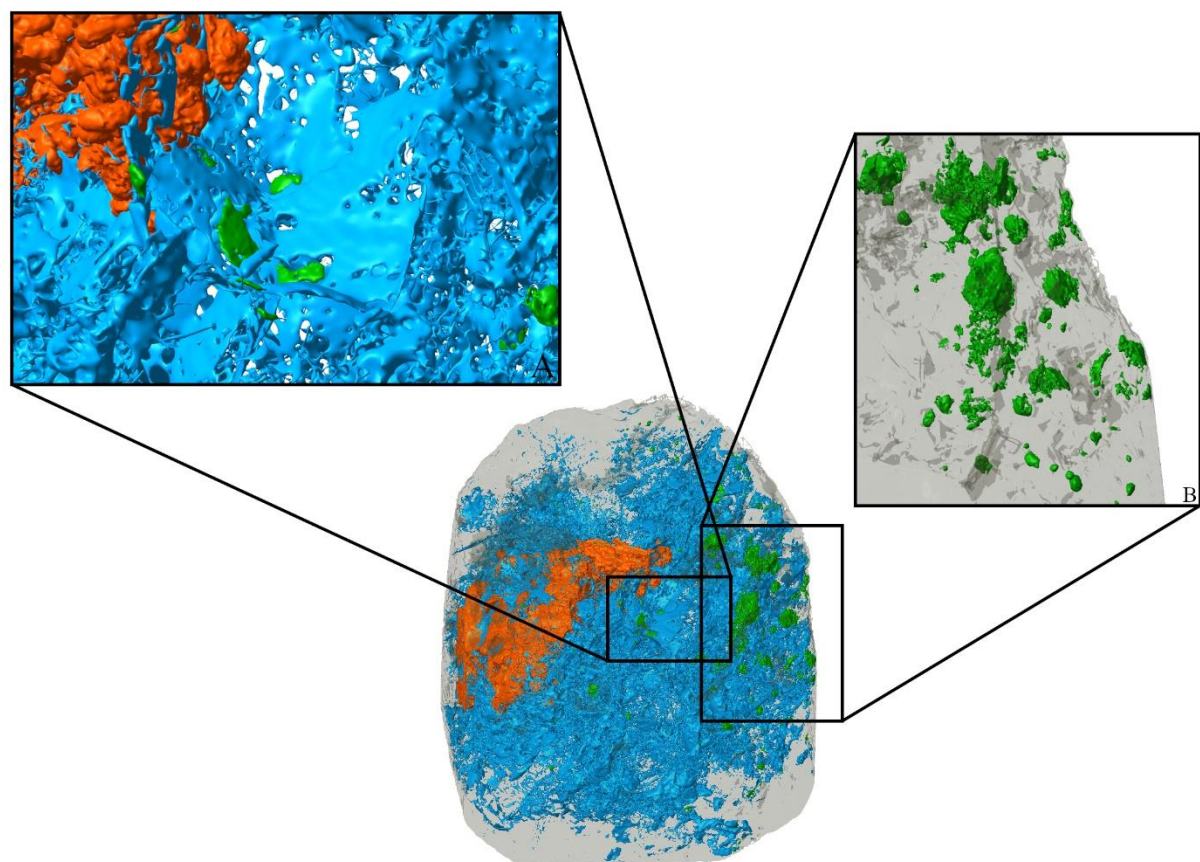


Figure 9: 3D reconstruction of a volume of interest in mantle xenolith Bi4 obtained at step C (see text and Table 1), 1833x1949x1852 voxels. Spinel segmented in orange, voids in blue and high-density phases in green. A) Detail of voids and high-density phases crystallized inside fractures. B) Detail of the high-density phases at the top of our sample.

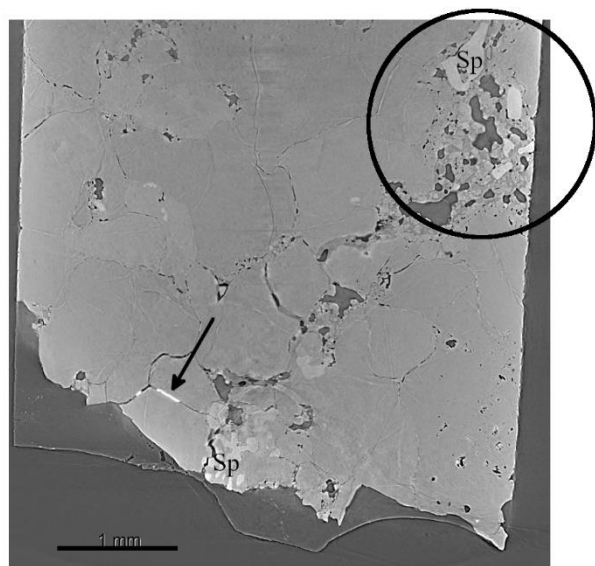


Figure 10: One of the slices composing the 3D model of Fig.9. Arrow indicating a high-density phase crystallized inside a fracture (see Fig.9A). Circle highlighting a microcrystalline bleb surrounding spinel (Sp).

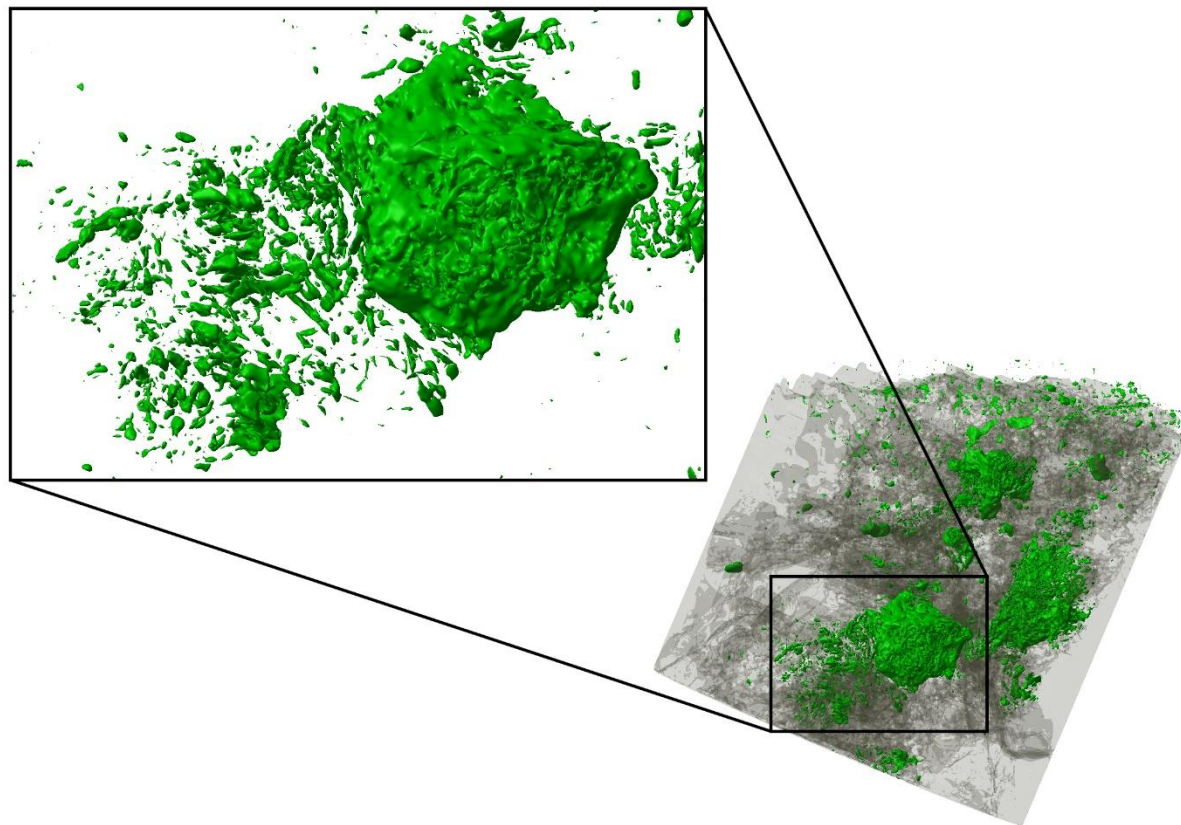


Figure 11: 3D reconstruction of a volume of interest in mantle xenolith Bi4 obtained at step D (see text and Table 1), 1865x1865x2048 voxels. High-density phases segmented in green.

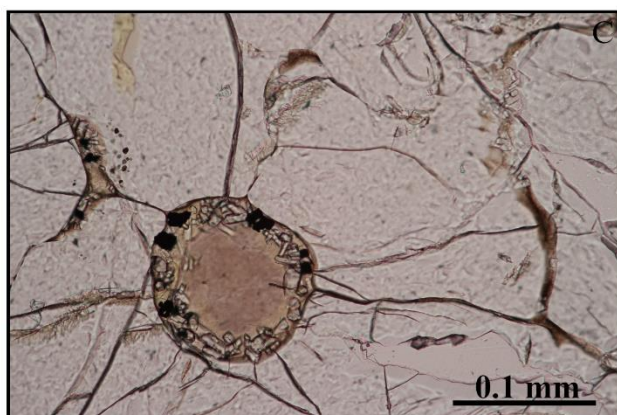
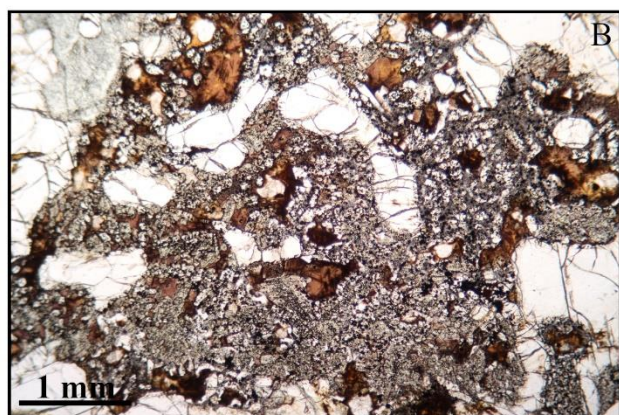
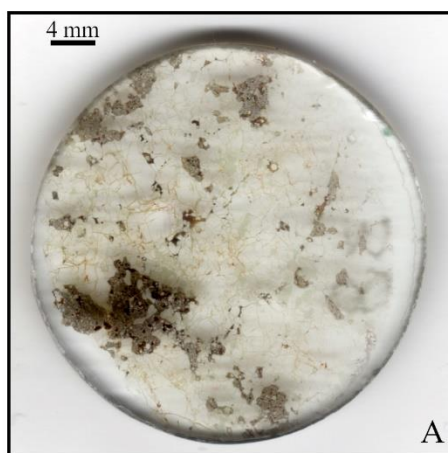


Figure 12: Thin section of mantle xenolith FN38 (A) and details of glassy patches with neoblasts crystallized inside (B and C) in plane polarized light.

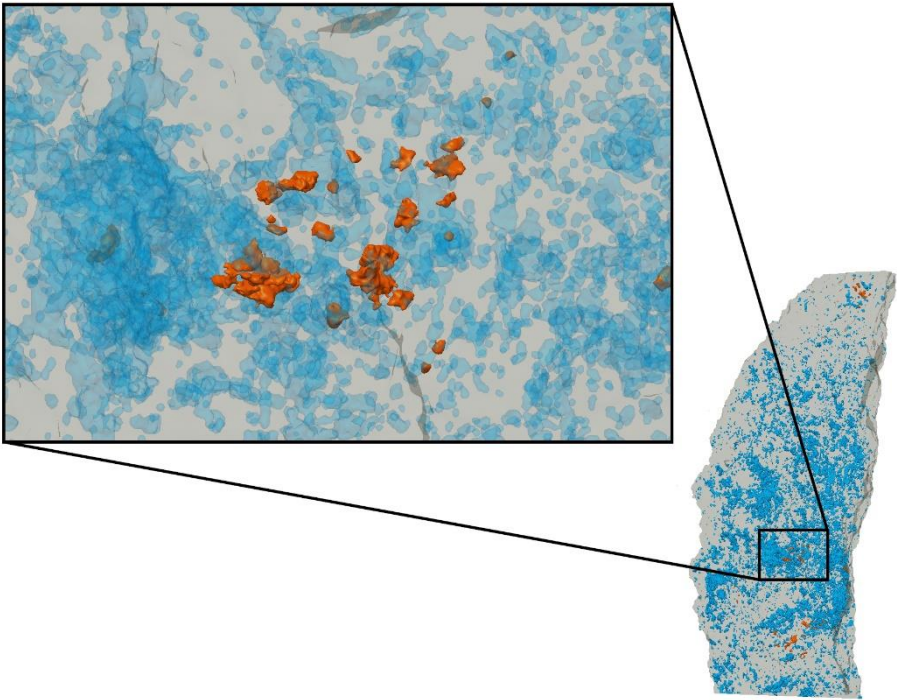


Figure 13: 3D reconstruction of mantle xenolith FN38 obtained at step A (see text and Table 1), 1121x764x2151 voxels. Spinel segmented in orange, glass in blue.

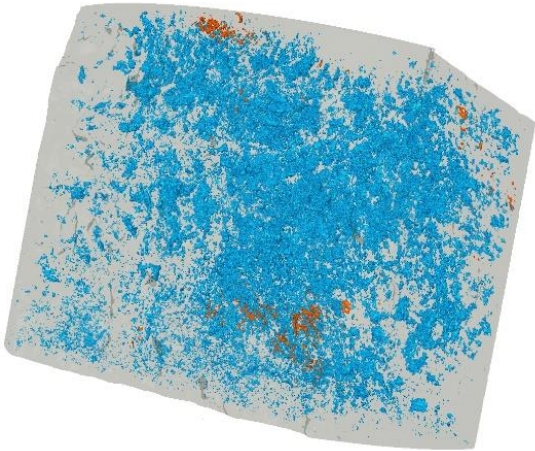
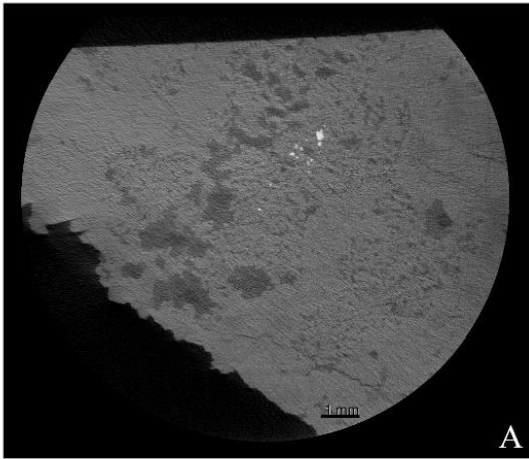
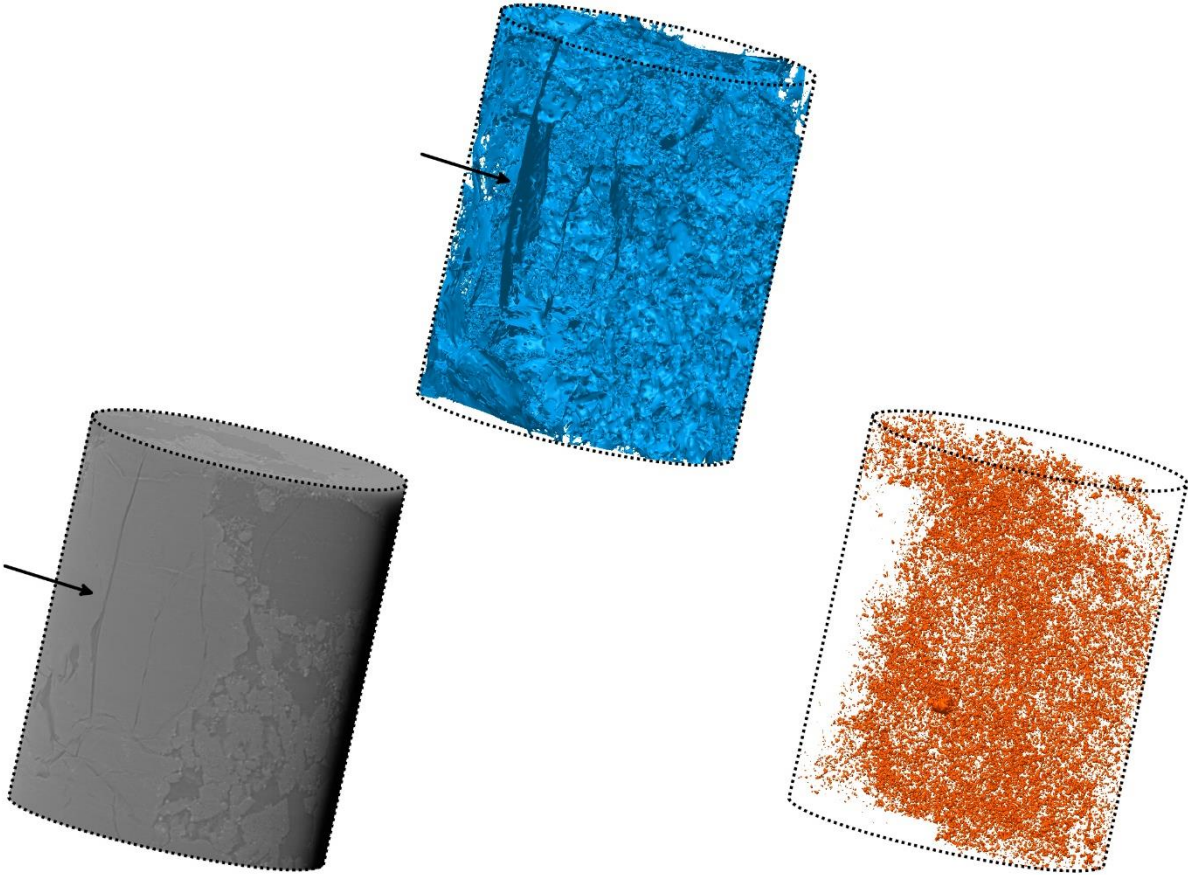
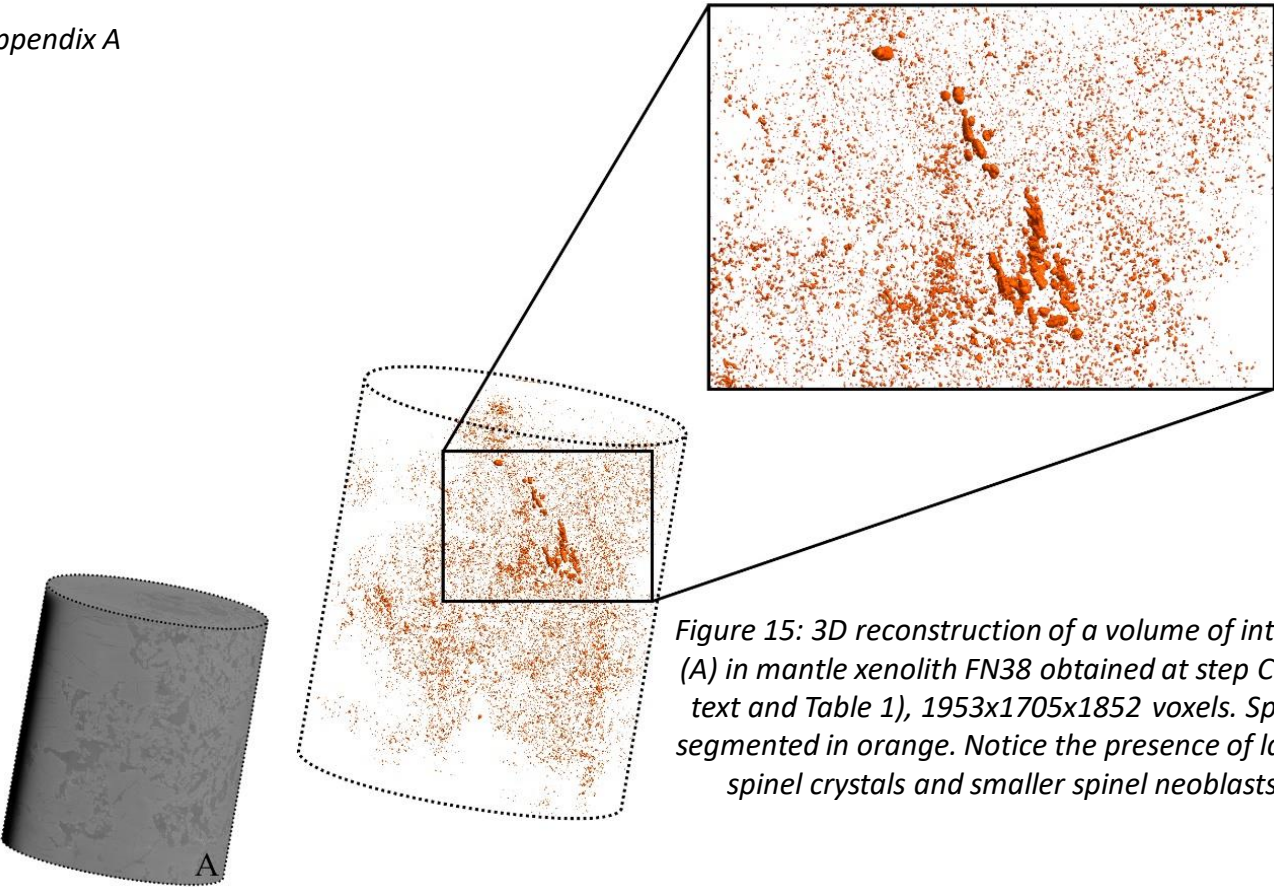


Figure 14: 3D reconstruction of a volume of interest in mantle xenolith FN38 obtained at step B (see text and Table 1), 1970x1700x1256 voxels. Spinel segmented in orange, glass in blue. A) One of the slices composing the 3D model; notice the absence of spinel (white) inside glassy patches (dark grey).



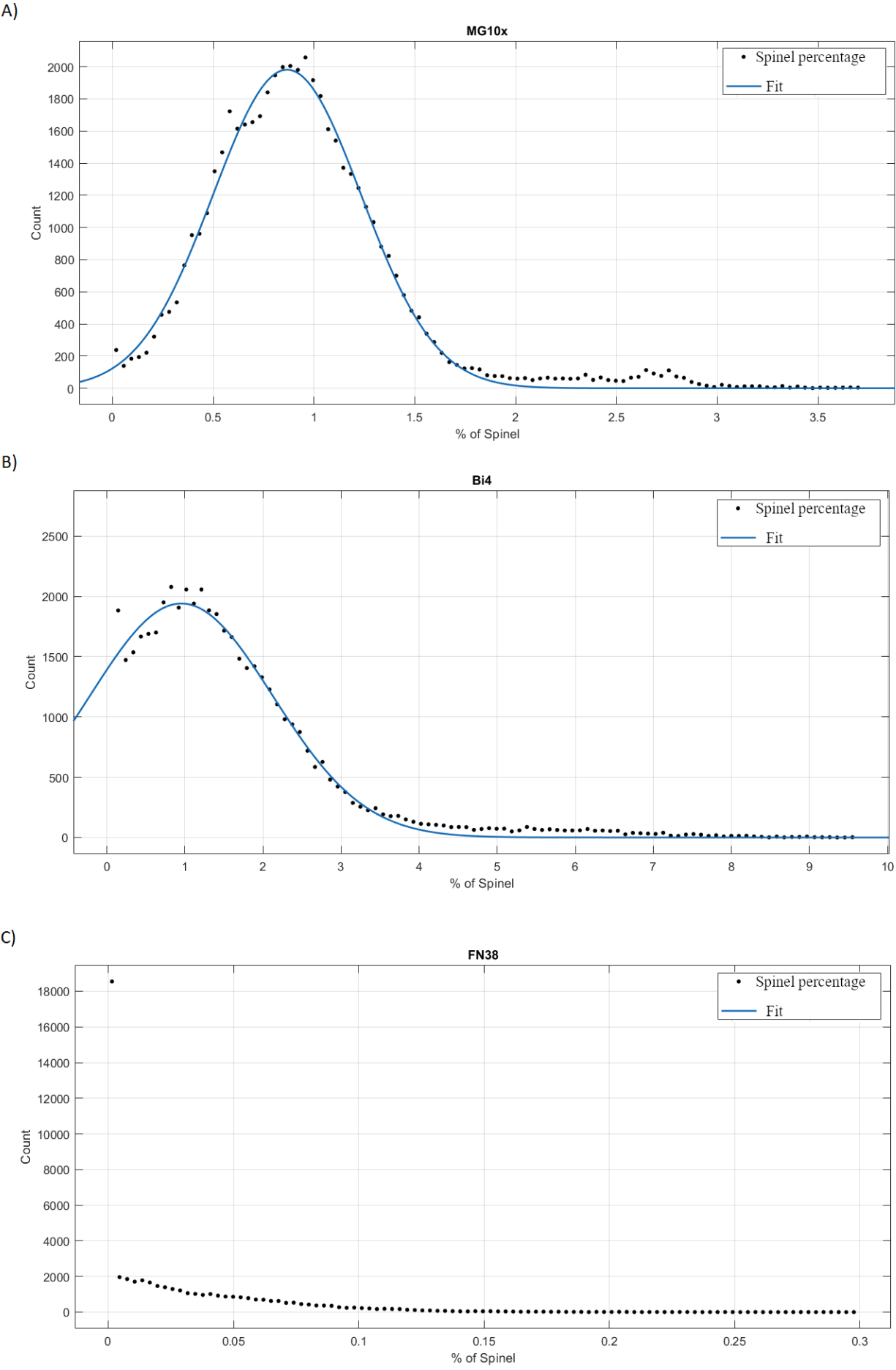
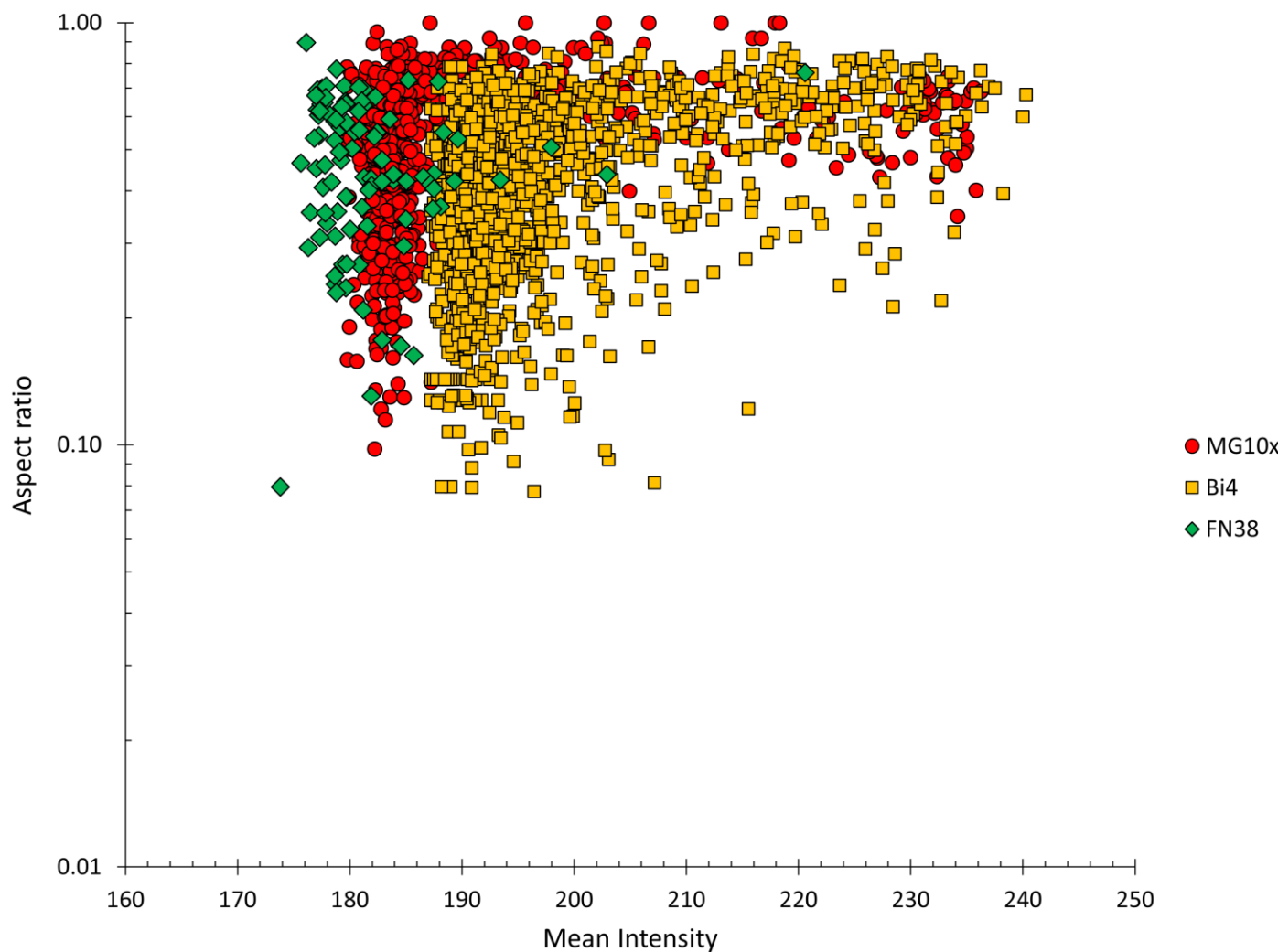
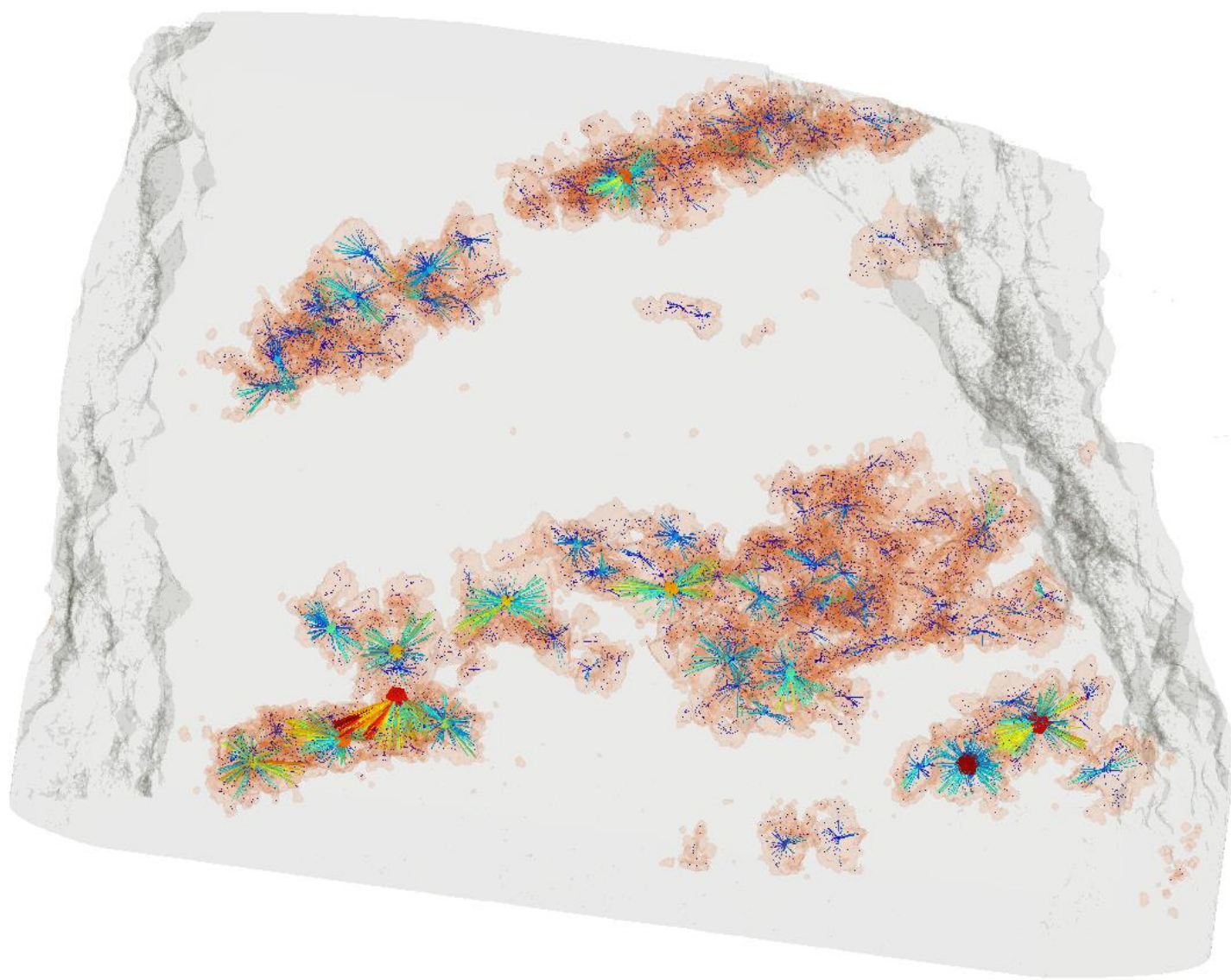


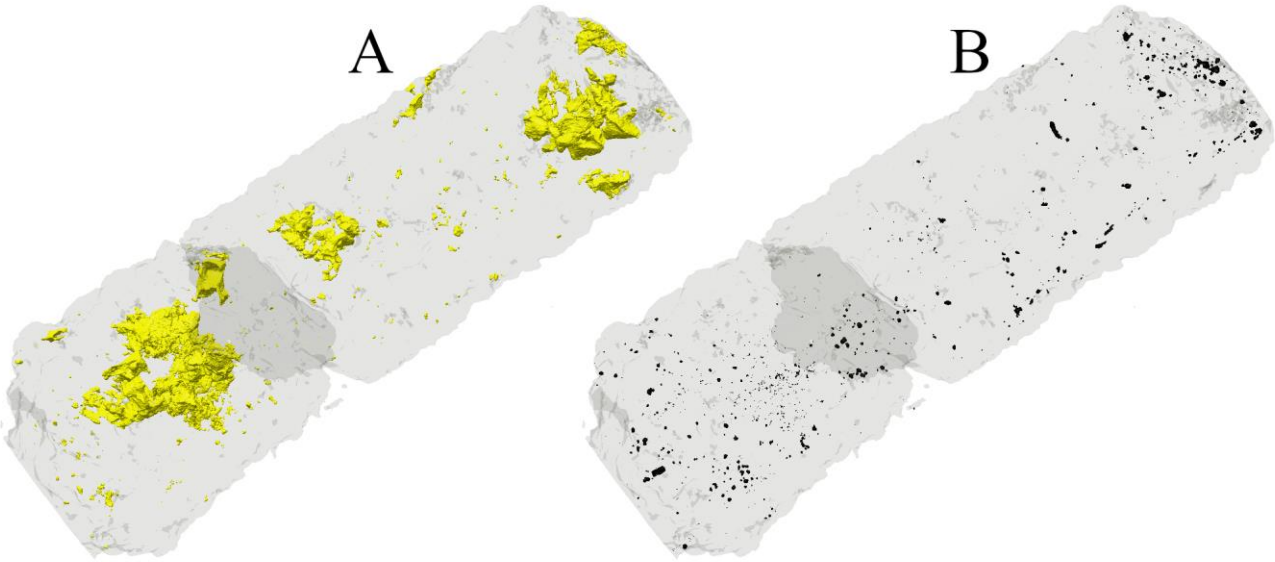
Figure 17: Results of the simulation on 50000 random sections taken in the 3D models of the xenoliths obtained via ICTP data (steps A in Table1), and relative fit.



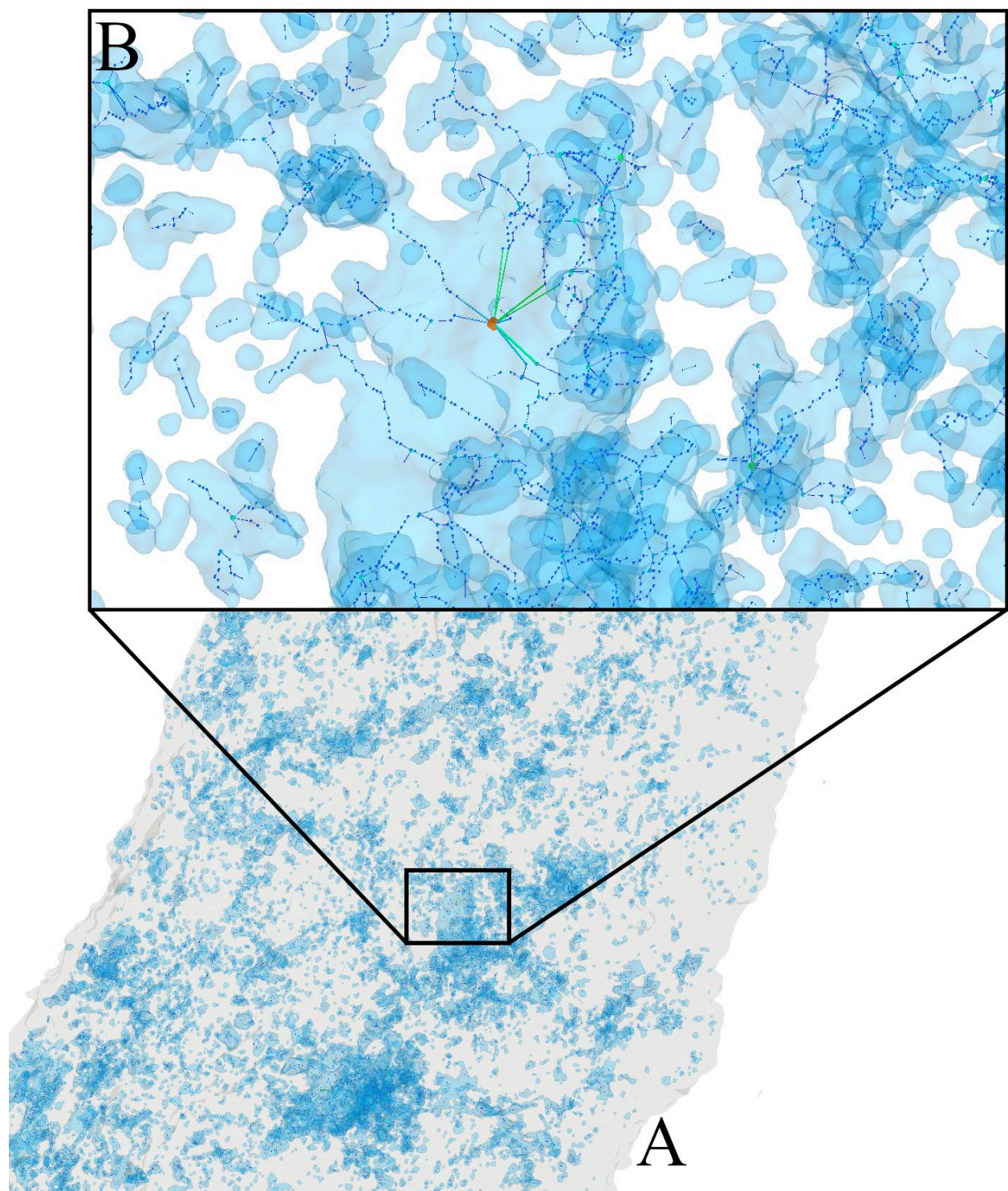
Supplementary Figure S2: Graph showing Mean intensity vs. Aspect ratio for the high intensity volumes segmented from the three xenoliths. Data obtained through connected components analysis at step A (see electronic supplement S1).



Supplementary Figure S3: 3D model obtained at step B for mantle xenolith MG10x. Silicates in light grey, spinel in light orange. Skeleton analysis is visible inside spinel, with color spectrum ranging from blue (lowest connectivity) to red (highest connectivity). Radius of vertices reflecting their connectivity and edge radius reflecting Euclidean length of edges.



Supplementary Figure S4: 3D model obtained at step A for mantle xenolith Bi4. Silicates in light grey. Here the subdivision of high intensity ROI into: A) low Volume/Surface ratio (in yellow); B) high volume/surface ratio (in black). Notice how yellow highlighted volumes match spinel of Fig. 7.



Supplementary Figure S5: A) 3D model obtained at step A for mantle xenolith FN38. Glass in light blue, silicates in light grey. B) inset showing skeleton analysis inside glasses, with color spectrum ranging from blue (lowest connectivity) to red (highest connectivity). Radius of vertices reflecting their connectivity and edge radius reflecting Euclidean length of edges.

Appendix B

Connected component analyses (CA) have been exported from the software Dragonfly as Excel spreadsheet.

For every single volume segmented inside a 3D Model, CA analyses give values of the requested parameters (resumed in the methods section of this thesis). CA results consist in a file with several thousand rows, for this reason, it was impossible to conventionally attach results as paper files.

Considering that the uploading process of the dissertation does not allow attaching electronic supplements, Appendix B is given as a link to a Dropbox folder in which the reader will find all the CA analyses made in step B of μ -CT and the Supplementary_data_S1.

Link:

<https://www.dropbox.com/scl/fo/wotyf2v8ew3zal7xz0ya6/h?dl=0&rlkey=omyrxpj2sptmlrpq45ei0ufhw>

In case the link does not work, data are available under request to the author.

Sample	Type	Spot	MgO	Al ₂ O ₃	SiO ₂	TiO ₂	Cr ₂ O ₃	MnO	FeO	NiO	Tot	Si
14-1-5	2	core	14.71	31.45	0.0633	2.33	29.04	0.1218	24.66	0.2364	102.61	0.0018
14-1-6	2	rim	12.14	23.23	0.0495	8.63	23.03	0.2224	33.15	0.4586	100.91	0.0015
14-2-11	2	core	11.8	21.97	0.0391	9.41	22.62	0.2797	34.96	0.2908	101.37	0.0012
14-3-1	2	core	11.53	13.92	0.031	5.04	41.26	0.1513	29.66	0.2392	101.83	0.0010
14-3-2	2	core	13.17	24.1	0.0081	6.38	27.18	0.2566	30.78	0.3801	102.25	0.0002
18-1-10	2	core	8.64	7.22	0.0416	19.74	9.57	0.3469	54.23	0.3049	100.09	0.0014
18-1-11	2	core	8.47	6.84	0.0763	20.77	7.67	0.3841	56.02	0.2649	100.50	0.0025
18-2-13	2	core	8.93	8.47	0.0457	18.16	10.47	0.3129	52.94	0.2608	99.59	0.0015
18-2-14	2	core	8.67	6.73	0.0708	21.16	8.29	0.3654	54.62	0.3158	100.22	0.0024
30-1-17	2	core	12.13	13.35	0.0037	9.96	32.14	0.2915	32.73	0.2696	100.87	0.0001
30-1-18	2	core	11.35	10.58	0.0834	11.73	30.21	0.2682	35.02	0.328	99.57	0.0027
30-1-19	2	core	11.44	15.98	0.0861	7.09	34.73	0.2243	31.19	0.3567	101.10	0.0027
30-3-11	1	rim	10.67	12.31	0.0548	12.09	25.42	0.339	39.29	0.3323	100.51	0.0018
30-3-12	1	core	13.48	26.36	0.0658	2.65	33.21	0.1758	25.65	0.2047	101.80	0.0019
30-3-13	1	core	14.81	35.27	0.0124	0.123	29.98	0.1646	21.37	0.2731	102.00	0.0004
38-1-3	2	core	8.84	9.05	0.0754	16.36	15.1	0.4838	49.59	0.2579	99.76	0.0025
38-1-4	2	core	9.11	9.7	0.0838	16.12	15.27	0.4529	48.36	0.2701	99.37	0.0028
38-2-12	2	core	13.53	20.14	0.0427	7.67	30.27	0.3097	28.37	0.2963	100.63	0.0013
38-3-10	2	core	8.9	9.1	0.6507	16.94	14.69	0.4323	48.52	0.2718	99.50	0.0217
38-3-18	2	core	9.96	10.86	0.8521	14.94	17.95	0.3691	44.06	0.2847	99.28	0.0280
38-3-19	2	core	8.8	9.08	0.0394	15.92	13.75	0.4239	51.37	0.302	99.69	0.0013
38-4-16	2	core	14.53	28.26	0.3887	5.71	23.76	0.2421	27.53	0.3333	100.75	0.0114
38-4-2	2	core	12.84	25.67	3.55	6.31	22.97	0.2016	26.85	0.3476	98.74	0.1078
38-5-5	2	core	11.22	13.37	0.1088	13.28	22.6	0.2603	39.13	0.3898	100.36	0.0035
38-5-6	2	core	10.79	13.38	0.7359	13.56	21.25	0.3254	39.18	0.4278	99.65	0.0237
41-2-3	2	core	19.65	45.19	0.0634	0.1327	23.25	0.0923	14.19	0.2193	102.79	0.0017
41-2-4	2	rim	16.54	36.34	0.0406	1.2577	30.86	0.159	15.68	0.2564	101.13	0.0011
41-3-10	1	core	16.81	42.44	0.0655	0.2677	24.93	0.103	17.53	0.2434	102.39	0.0018
41-3-11	1	rim	15.5	29.25	0.1042	5.12	25.72	0.2405	25.56	0.3762	101.87	0.0030
41-3-5	2	core	14.72	38.34	0.0367	1.5645	23.41	0.1248	23.57	0.2653	102.03	0.0010
41-3-6	2	rim	12.7	21.63	0.0463	8.49	22.37	0.2588	34.16	0.3371	99.99	0.0014

Sample	Type	Spot	Ti	Al	Cr	Fe3+	Fe2+	Mn	Mg	Ni	Tot	Cr/ (Cr+Al)
14-1-5	2	core	0.0502	1.0622	0.6580	0.1758	0.4152	0.0030	0.6284	0.0054	3.0000	0.38
14-1-6	2	rim	0.1977	0.8338	0.5545	0.2132	0.6311	0.0057	0.5512	0.0112	3.0000	0.40
14-2-11	2	core	0.2163	0.7911	0.5464	0.2276	0.6657	0.0072	0.5374	0.0071	3.0000	0.41
14-3-1	2	core	0.1195	0.5172	1.0284	0.2134	0.5685	0.0040	0.5419	0.0061	3.0000	0.67
14-3-2	2	core	0.1431	0.8470	0.6408	0.2254	0.5423	0.0065	0.5855	0.0091	3.0000	0.43
18-1-10	2	core	0.4965	0.2845	0.2529	0.4669	1.0492	0.0098	0.4306	0.0082	3.0000	0.47
18-1-11	2	core	0.5218	0.2692	0.2025	0.4797	1.0847	0.0109	0.4216	0.0071	3.0000	0.43
18-2-13	2	core	0.4553	0.3326	0.2758	0.4780	0.9973	0.0088	0.4436	0.0070	3.0000	0.45
18-2-14	2	core	0.5327	0.2654	0.2193	0.4450	1.0837	0.0104	0.4325	0.0085	3.0000	0.45
30-1-17	2	core	0.2377	0.4992	0.8062	0.2190	0.6494	0.0078	0.5737	0.0069	3.0000	0.62
30-1-18	2	core	0.2879	0.4068	0.7792	0.2328	0.7226	0.0074	0.5520	0.0086	3.0000	0.66
30-1-19	2	core	0.1679	0.5927	0.8641	0.2020	0.6189	0.0060	0.5367	0.0090	3.0000	0.59
30-3-11	1	rim	0.2932	0.4676	0.6478	0.2947	0.7644	0.0093	0.5127	0.0086	3.0000	0.58
30-3-12	1	core	0.0591	0.9206	0.7780	0.1793	0.4563	0.0044	0.5955	0.0049	3.0000	0.46
30-3-13	1	core	0.0026	1.1800	0.6728	0.1412	0.3661	0.0040	0.6267	0.0062	3.0000	0.36
38-1-3	2	core	0.4091	0.3545	0.3968	0.4254	0.9531	0.0136	0.4380	0.0069	3.0000	0.53
38-1-4	2	core	0.4027	0.3796	0.4009	0.4084	0.9346	0.0127	0.4510	0.0072	3.0000	0.51
38-2-12	2	core	0.1769	0.7275	0.7335	0.1826	0.5446	0.0080	0.6182	0.0073	3.0000	0.50
38-3-10	2	core	0.4240	0.3569	0.3864	0.3653	0.9848	0.0122	0.4415	0.0073	3.0000	0.52
38-3-18	2	core	0.3692	0.4205	0.4662	0.3188	0.8917	0.0103	0.4878	0.0075	3.0000	0.53
38-3-19	2	core	0.3980	0.3556	0.3613	0.4844	0.9434	0.0119	0.4360	0.0081	3.0000	0.50
38-4-16	2	core	0.1264	0.9802	0.5529	0.1911	0.4864	0.0060	0.6375	0.0079	3.0000	0.36
38-4-2	2	core	0.1442	0.9190	0.5517	0.0252	0.6569	0.0052	0.5815	0.0085	3.0000	0.38
38-5-5	2	core	0.3198	0.5045	0.5720	0.2769	0.7708	0.0071	0.5355	0.0100	3.0000	0.53
38-5-6	2	core	0.3292	0.5088	0.5421	0.2433	0.8139	0.0089	0.5190	0.0111	3.0000	0.52
41-2-3	2	core	0.0026	1.4112	0.4871	0.0931	0.2214	0.0021	0.7762	0.0047	3.0000	0.26
41-2-4	2	rim	0.0267	1.2084	0.6884	0.0475	0.3225	0.0038	0.6957	0.0058	3.0000	0.36
41-3-10	1	core	0.0055	1.3642	0.5376	0.0837	0.3161	0.0024	0.6835	0.0053	3.0000	0.28
41-3-11	1	rim	0.1114	0.9968	0.5880	0.1865	0.4316	0.0059	0.6681	0.0088	3.0000	0.37
41-3-5	2	core	0.0330	1.2683	0.5195	0.1441	0.4092	0.0030	0.6159	0.0060	3.0000	0.29
41-3-6	2	rim	0.1963	0.7836	0.5436	0.2773	0.6007	0.0067	0.5819	0.0083	3.0000	0.41

Sample	Type	Spot	Fe3+/ (Fe3++Cr+Al)	Mg/ (Mg+Fe2+)
14-1-5	2	core	0.09	0.60
14-1-6	2	rim	0.13	0.47
14-2-11	2	core	0.15	0.45
14-3-1	2	core	0.12	0.49
14-3-2	2	core	0.13	0.52
18-1-10	2	core	0.46	0.29
18-1-11	2	core	0.50	0.28
18-2-13	2	core	0.44	0.31
18-2-14	2	core	0.48	0.29
30-1-17	2	core	0.14	0.47
30-1-18	2	core	0.16	0.43
30-1-19	2	core	0.12	0.46
30-3-11	1	rim	0.21	0.40
30-3-12	1	core	0.10	0.57
30-3-13	1	core	0.07	0.63
38-1-3	2	core	0.36	0.31
38-1-4	2	core	0.34	0.33
38-2-12	2	core	0.11	0.53
38-3-10	2	core	0.33	0.31
38-3-18	2	core	0.26	0.35
38-3-19	2	core	0.40	0.32
38-4-16	2	core	0.11	0.57
38-4-2	2	core	0.02	0.47
38-5-5	2	core	0.20	0.41
38-5-6	2	core	0.19	0.39
41-2-3	2	core	0.05	0.78
41-2-4	2	rim	0.02	0.68
41-3-10	1	core	0.04	0.68
41-3-11	1	rim	0.11	0.61
41-3-5	2	core	0.07	0.60
41-3-6	2	rim	0.17	0.49

Sample	Type	Spot	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	MnO
14-1-1	1	core	0.0369	47.22	0	39.64	0.0039	0.0524	0.0189	0.0358	0.1823
14-1-7	1	rim	0.0176	46.88	0.0104	39.84	0	0.2394	0.0348	0.0129	0.2166
14-2-3	1	trav: ol-core	0	46.87	0.0553	39.39	0.0122	0.2741	0.0608	0.1023	0.19
14-2-4	1	trav: ol	0.0014	47.53	0.0181	39.98	0.0117	0.1714	0.0319	0.0605	0.158
14-2-5	1	trav: ol	0.0197	47.93	0.0231	39.72	0	0.1537	0	0.0294	0.2305
14-2-6	1	trav: ol	0.0487	47.87	0.0519	39.62	0.0009	0.1211	0	0.0071	0.2304
14-2-7	1	trav: ol-rim	0.024	47.14	0.0116	39.85	0.0131	0.1032	0.0449	0.0035	0.196
14-3-5	1	core	0.0552	46.77	0.0284	39.91	0.0131	0.0891	0	0.0038	0.2571
14-3-6	1	rim	0.0027	46.54	0	39.96	0	0.2459	0.0087	0	0.2404
18-1-14	1	rim	0.0501	41.43	0.0209	39.08	0.0193	0.2956	0.097	0.0261	0.2492
18-1-15	1	core	0.0899	41.88	0.0374	38.92	0.0135	0.1749	0.0214	0.037	0.2016
18-1-8	1	rim	0.0631	41.61	0.0034	39.26	0.0132	0.318	0.0371	0.0268	0.2871
18-1-9	1	core	0.0242	42.44	0.0202	39.13	0.0098	0.1013	0.0057	0	0.3001
18-2-10	1	rim	0.0989	41.44	0.0251	39.47	0	0.2735	0.0229	0.0216	0.2135
18-2-19	1	rim	0.0656	42.05	0.0514	39.39	0	0.2956	0	0	0.1836
18-2-20	1	core	0.0776	42.21	0.0178	39.62	0.0072	0.1292	0.0402	0.0162	0.2295
18-2-7	2	rim	0.0504	43.32	0.0291	39.53	0	0.1792	0.0229	0.0118	0.2332
18-2-8	2	core	0.0568	41.86	0.0522	39.19	0.0227	0.3246	0.0257	0.0329	0.2862
18-2-9	1	core	0.0608	42.3	0	39.41	0	0.0751	0.0157	0.0481	0.2307
30-1-1	1	trav: ol-rim	0.0317	45.41	0.0007	39.38	0.0067	0.2404	0.0867	0.038	0.2229
30-1-11	2	core	0.0629	45.43	0	39.64	0	0.1832	0.0145	0.0245	0.1793
30-1-12	2	rim	0.0384	45.42	0.0317	39.95	0.0012	0.2635	0.0608	0.0424	0.2165
30-1-2	1	trav: ol	0.0382	45.55	0.0285	39.86	0	0.1864	0	0.0203	0.2173
30-1-3	1	trav: ol	0.0547	46.57	0.0427	39.72	0.0066	0.1916	0.0073	0	0.2973
30-1-4	1	trav: ol	0.0045	47.07	0.0124	40.04	0.0068	0.1641	0	0.0593	0.1598
30-1-5	1	trav: ol	0	48.66	0.0069	40.64	0.0111	0.0428	0	0.035	0.1514
30-1-6	1	trav: ol-core	0.0252	49.37	0.0188	40.45	0.0086	0.07	0	0.005	0.1905
30-3-10	1	rim	0.03	45.17	0.0505	39.12	0.0142	0.2217	0.0217	0	0.277
30-3-5	2	core	0.0598	45.71	0.0492	40.02	0.0083	0.1573	0	0.0174	0.2427
30-3-6	2	rim	0	44.15	0.0077	39.85	0.0205	0.2613	0.0649	0.0234	0.2675
30-3-9	1	core	0.0271	47.87	0	40.14	0	0.0924	0	0.019	0.1226
38-1-1	1	core	0.0612	48.63	0.0308	39.85	0.0057	0.0368	0.0189	0	0.1942
38-1-13	2	core	0.035	44.7	0.0371	39.24	0.0055	0.2707	0.072	0	0.2342
38-1-2	1	rim	0.0334	44.75	0.0329	39.7	0.0016	0.2845	0.0576	0.008	0.2729
38-1-7	2	core	0.0378	45.09	0.061	39.22	0.0044	0.3852	0.0532	0.025	0.3325
38-1-8	2	rim	0	44.14	0.08	39.82	0.0028	0.3448	0.1238	0.0822	0.2398
38-2-1	2	core	0.0093	48.29	0.0295	40.09	0	0.04	0	0	0.2212
38-2-10	2	core	0.0293	48.25	0.0304	40.04	0.0112	0.0361	0.0146	0	0.2204
38-2-11	2	rim	0.0122	48.15	0.026	39.23	0.0174	0.2003	0.0421	0.0655	0.2153
38-2-2	2	rim	0.0046	48.03	0.002	40.36	0	0.2521	0.0377	0	0.2314
38-2-3	1	core	0.0309	48.32	0.004	39.93	0.0053	0.0709	0.0247	0.0199	0.2505
38-2-4	1	rim	0	48.23	0.0411	39.55	0	0.2175	0.0435	0	0.2173
38-2-5	1	core	0.0221	48.49	0.0255	39.82	0.0013	0.0507	0.0232	0	0.2027
38-3-20	1	core	0.0097	48.55	0.0327	39.64	0.013	0.051	0.0029	0	0.2218
38-3-21	1	rim	0.0485	44.65	0.036	37.97	0.0153	0.3056	0.0416	0.105	0.278
38-3-5	2	core	0.0147	43.44	0.021	38.22	0.0053	0.3076	0.0416	0	0.288
38-3-6	2	rim	0.0208	43.68	0.0471	38.38	0.0155	0.315	0.1319	0.0403	0.2639
38-3-7	2	core	0.0465	43.68	0.0223	38.83	0	0.2997	0.1018	0.1523	0.328
38-3-8	2	rim	0.0592	43.16	0.0346	38.83	0.0183	0.3041	0.1864	0.1221	0.2604
38-4-10	2	rim	0.0105	46.55	0.0528	39.28	0.0026	0.2761	0.0536	0.0225	0.2184
38-4-14	1	core	0.033	48.12	0.0126	40.14	0	0.0655	0	0	0.2699
38-4-15	1	rim	0.0351	47.26	0.0435	39.72	0	0.2017	0.0651	0.0041	0.2242
38-4-19	2	core	0.0135	46.71	0.0358	39.64	0	0.2534	0.0014	0.0717	0.2621
38-4-20	2	rim	0.0088	47.19	0.0097	39.46	0.0173	0.2582	0.0564	0.0251	0.2388
38-4-23	1	core	0.034	47.54	0	39.94	0.0046	0.0491	0	0	0.2465

Sample	Type	Spot	FeO	NiO	Tot	Si	Ti	Al	Cr	Fe ²⁺	Ni
14-1-1	1	core	13.42	0.366	100.98	0.9817	0.0004	0.0000	0.0007	0.2780	0.0073
14-1-7	1	rim	13.26	0.3502	100.86	0.9869	0.0006	0.0003	0.0003	0.2747	0.0070
14-2-3	1	trav: ol-core	13.85	0.377	101.18	0.9768	0.0011	0.0016	0.0020	0.2872	0.0075
14-2-4	1	trav: ol	13.48	0.3217	101.76	0.9822	0.0006	0.0005	0.0012	0.2770	0.0064
14-2-5	1	trav: ol	13.32	0.3238	101.75	0.9762	0.0000	0.0007	0.0006	0.2738	0.0064
14-2-6	1	trav: ol	13.3	0.3876	101.64	0.9752	0.0000	0.0015	0.0001	0.2738	0.0077
14-2-7	1	trav: ol-rim	13.19	0.2906	100.87	0.9862	0.0008	0.0003	0.0001	0.2730	0.0058
14-3-5	1	core	13.93	0.3749	101.43	0.9859	0.0000	0.0008	0.0001	0.2878	0.0075
14-3-6	1	rim	14.03	0.2641	101.29	0.9883	0.0002	0.0000	0.0000	0.2902	0.0053
18-1-14	1	rim	19.45	0.2085	100.93	0.9947	0.0019	0.0006	0.0005	0.4140	0.0043
18-1-15	1	core	18.28	0.2251	99.88	0.9958	0.0004	0.0011	0.0007	0.3912	0.0046
18-1-8	1	rim	19.23	0.2277	101.08	0.9967	0.0007	0.0001	0.0005	0.4083	0.0047
18-1-9	1	core	19.06	0.253	101.34	0.9900	0.0001	0.0006	0.0000	0.4033	0.0051
18-2-10	1	rim	18.75	0.2026	100.52	1.0041	0.0004	0.0008	0.0004	0.3989	0.0041
18-2-19	1	rim	18.47	0.2124	100.72	0.9990	0.0000	0.0015	0.0000	0.3918	0.0043
18-2-20	1	core	18.35	0.2725	100.97	1.0015	0.0008	0.0005	0.0003	0.3879	0.0055
18-2-7	2	rim	17.51	0.2433	101.13	0.9944	0.0004	0.0009	0.0002	0.3683	0.0049
18-2-8	2	core	19	0.2205	101.07	0.9943	0.0005	0.0016	0.0007	0.4031	0.0045
18-2-9	1	core	19.11	0.1743	101.42	0.9951	0.0003	0.0000	0.0010	0.4035	0.0035
30-1-1	1	trav: ol-rim	15.09	0.3289	100.84	0.9845	0.0016	0.0000	0.0008	0.3155	0.0066
30-1-11	2	core	14.2	0.3164	100.05	0.9935	0.0003	0.0000	0.0005	0.2976	0.0064
30-1-12	2	rim	14.5	0.3067	100.83	0.9945	0.0011	0.0009	0.0008	0.3019	0.0061
30-1-2	1	trav: ol	14.82	0.3188	101.04	0.9917	0.0000	0.0008	0.0004	0.3084	0.0064
30-1-3	1	trav: ol	14.04	0.3316	101.26	0.9840	0.0001	0.0012	0.0000	0.2909	0.0066
30-1-4	1	trav: ol	12.87	0.3588	100.75	0.9904	0.0000	0.0004	0.0012	0.2662	0.0071
30-1-5	1	trav: ol	11.03	0.2977	100.87	0.9942	0.0000	0.0002	0.0007	0.2257	0.0059
30-1-6	1	trav: ol-core	10.6	0.3212	101.06	0.9871	0.0000	0.0005	0.0001	0.2163	0.0063
30-3-10	1	rim	14.88	0.3505	100.14	0.9846	0.0004	0.0015	0.0000	0.3132	0.0071
30-3-5	2	core	14.88	0.3712	101.52	0.9914	0.0000	0.0014	0.0003	0.3083	0.0074
30-3-6	2	rim	15.82	0.2443	100.71	0.9988	0.0012	0.0002	0.0005	0.3316	0.0049
30-3-9	1	core	11.37	0.3027	99.94	0.9933	0.0000	0.0000	0.0004	0.2353	0.0060
38-1-1	1	core	12.7	0.3854	101.91	0.9751	0.0003	0.0009	0.0000	0.2599	0.0076
38-1-13	2	core	16.31	0.2555	101.16	0.9831	0.0014	0.0011	0.0000	0.3417	0.0051
38-1-2	1	rim	16.5	0.1956	101.84	0.9876	0.0011	0.0010	0.0002	0.3433	0.0039
38-1-7	2	core	16.35	0.2501	101.81	0.9776	0.0010	0.0018	0.0005	0.3408	0.0050
38-1-8	2	rim	16.29	0.2568	101.38	0.9938	0.0023	0.0024	0.0016	0.3400	0.0052
38-2-1	2	core	12.03	0.3391	101.05	0.9851	0.0000	0.0009	0.0000	0.2472	0.0067
38-2-10	2	core	11.88	0.3495	100.86	0.9853	0.0003	0.0009	0.0000	0.2445	0.0069
38-2-11	2	rim	11.99	0.2955	100.24	0.9740	0.0008	0.0008	0.0013	0.2490	0.0059
38-2-2	2	rim	12.86	0.3177	102.10	0.9852	0.0007	0.0001	0.0000	0.2625	0.0062
38-2-3	1	core	11.99	0.3361	100.98	0.9824	0.0005	0.0001	0.0004	0.2467	0.0067
38-2-4	1	rim	12.58	0.3642	101.24	0.9743	0.0008	0.0012	0.0000	0.2592	0.0072
38-2-5	1	core	12.35	0.3808	101.37	0.9778	0.0004	0.0007	0.0000	0.2536	0.0075
38-3-20	1	core	12.26	0.2585	101.04	0.9762	0.0001	0.0009	0.0000	0.2525	0.0051
38-3-21	1	rim	16.59	0.2394	100.28	0.9647	0.0008	0.0011	0.0021	0.3525	0.0049
38-3-5	2	core	17.13	0.2317	99.70	0.9775	0.0008	0.0006	0.0000	0.3664	0.0048
38-3-6	2	rim	17.42	0.2892	100.60	0.9742	0.0025	0.0014	0.0008	0.3698	0.0059
38-3-7	2	core	17.39	0.1813	101.03	0.9800	0.0019	0.0007	0.0030	0.3671	0.0037
38-3-8	2	rim	17.34	0.2301	100.55	0.9844	0.0036	0.0010	0.0024	0.3676	0.0047
38-4-10	2	rim	12.99	0.243	99.70	0.9838	0.0010	0.0016	0.0004	0.2721	0.0049
38-4-14	1	core	12.46	0.2742	101.38	0.9850	0.0000	0.0004	0.0000	0.2557	0.0054
38-4-15	1	rim	12.89	0.3244	100.77	0.9834	0.0012	0.0013	0.0001	0.2669	0.0065
38-4-19	2	core	13.55	0.2738	100.81	0.9841	0.0000	0.0010	0.0014	0.2813	0.0055
38-4-20	2	rim	13.58	0.2923	101.14	0.9775	0.0011	0.0003	0.0005	0.2813	0.0058
38-4-23	1	core	12.3	0.3299	100.44	0.9886	0.0000	0.0000	0.0000	0.2546	0.0066

Sample	Type	Spot	Mn	Mg	Ca	Na	Totale	Fo	Fa	Mg/ (Mg+Fe2+)
14-1-1	1	core	0.0038	1.7434	0.0014	0.0018	3.0184	86.09	13.72	86.25
14-1-7	1	rim	0.0045	1.7312	0.0064	0.0008	3.0126	86.11	13.66	86.31
14-2-3	1	trav: ol-core	0.0040	1.7327	0.0073	0.0000	3.0203	85.61	14.19	85.78
14-2-4	1	trav: ol	0.0033	1.7407	0.0045	0.0001	3.0164	86.13	13.70	86.27
14-2-5	1	trav: ol	0.0048	1.7562	0.0040	0.0009	3.0236	86.31	13.46	86.51
14-2-6	1	trav: ol	0.0048	1.7565	0.0032	0.0023	3.0251	86.31	13.45	86.52
14-2-7	1	trav: ol-rim	0.0041	1.7391	0.0027	0.0012	3.0133	86.26	13.54	86.43
14-3-5	1	core	0.0054	1.7225	0.0024	0.0026	3.0149	85.46	14.28	85.68
14-3-6	1	rim	0.0050	1.7160	0.0065	0.0001	3.0116	85.32	14.43	85.53
18-1-14	1	rim	0.0054	1.5721	0.0081	0.0025	3.0041	78.94	20.79	79.15
18-1-15	1	core	0.0044	1.5975	0.0048	0.0045	3.0050	80.15	19.63	80.33
18-1-8	1	rim	0.0062	1.5748	0.0086	0.0031	3.0038	79.17	20.52	79.41
18-1-9	1	core	0.0064	1.6007	0.0027	0.0012	3.0102	79.62	20.06	79.88
18-2-10	1	rim	0.0046	1.5716	0.0075	0.0049	2.9973	79.57	20.20	79.76
18-2-19	1	rim	0.0039	1.5899	0.0080	0.0032	3.0018	80.07	19.73	80.23
18-2-20	1	core	0.0049	1.5905	0.0035	0.0038	2.9993	80.19	19.56	80.39
18-2-7	2	rim	0.0050	1.6245	0.0048	0.0025	3.0059	81.31	18.44	81.52
18-2-8	2	core	0.0062	1.5832	0.0088	0.0028	3.0055	79.46	20.23	79.71
18-2-9	1	core	0.0049	1.5922	0.0020	0.0030	3.0056	79.58	20.17	79.78
30-1-1	1	trav: ol-rim	0.0047	1.6925	0.0064	0.0015	3.0142	84.09	15.68	84.29
30-1-11	2	core	0.0038	1.6974	0.0049	0.0031	3.0075	84.92	14.89	85.08
30-1-12	2	rim	0.0046	1.6856	0.0070	0.0019	3.0044	84.62	15.15	84.81
30-1-2	1	trav: ol	0.0046	1.6895	0.0050	0.0018	3.0086	84.37	15.40	84.57
30-1-3	1	trav: ol	0.0062	1.7198	0.0051	0.0026	3.0166	85.27	14.42	85.53
30-1-4	1	trav: ol	0.0033	1.7357	0.0043	0.0002	3.0089	86.56	13.28	86.70
30-1-5	1	trav: ol	0.0031	1.7746	0.0011	0.0000	3.0054	88.58	11.26	88.72
30-1-6	1	trav: ol-core	0.0039	1.7960	0.0018	0.0012	3.0132	89.08	10.73	89.25
30-3-10	1	rim	0.0059	1.6948	0.0060	0.0015	3.0150	84.16	15.55	84.40
30-3-5	2	core	0.0051	1.6881	0.0042	0.0029	3.0091	84.34	15.40	84.56
30-3-6	2	rim	0.0057	1.6497	0.0070	0.0000	2.9996	83.03	16.69	83.26
30-3-9	1	core	0.0026	1.7659	0.0024	0.0013	3.0072	88.13	11.74	88.24
38-1-1	1	core	0.0040	1.7739	0.0010	0.0029	3.0256	87.05	12.75	87.22
38-1-13	2	core	0.0050	1.6695	0.0073	0.0017	3.0158	82.80	16.95	83.01
38-1-2	1	rim	0.0058	1.6596	0.0076	0.0016	3.0115	82.62	17.09	82.86
38-1-7	2	core	0.0070	1.6754	0.0103	0.0018	3.0212	82.81	16.84	83.10
38-1-8	2	rim	0.0051	1.6423	0.0092	0.0000	3.0019	82.64	17.11	82.85
38-2-1	2	core	0.0046	1.7688	0.0011	0.0004	3.0147	87.54	12.23	87.74
38-2-10	2	core	0.0046	1.7700	0.0010	0.0014	3.0147	87.66	12.11	87.86
38-2-11	2	rim	0.0045	1.7822	0.0053	0.0006	3.0244	87.55	12.23	87.74
38-2-2	2	rim	0.0048	1.7478	0.0066	0.0002	3.0142	86.73	13.03	86.94
38-2-3	1	core	0.0052	1.7723	0.0019	0.0015	3.0176	87.55	12.19	87.78
38-2-4	1	rim	0.0045	1.7713	0.0057	0.0000	3.0243	87.04	12.74	87.24
38-2-5	1	core	0.0042	1.7751	0.0013	0.0011	3.0219	87.32	12.48	87.50
38-3-20	1	core	0.0046	1.7823	0.0013	0.0005	3.0235	87.39	12.38	87.59
38-3-21	1	rim	0.0060	1.6912	0.0083	0.0024	3.0341	82.51	17.20	82.75
38-3-5	2	core	0.0062	1.6563	0.0084	0.0007	3.0217	81.63	18.06	81.89
38-3-6	2	rim	0.0057	1.6528	0.0086	0.0010	3.0227	81.49	18.23	81.72
38-3-7	2	core	0.0070	1.6435	0.0081	0.0023	3.0173	81.46	18.19	81.74
38-3-8	2	rim	0.0056	1.6312	0.0083	0.0029	3.0117	81.38	18.34	81.61
38-4-10	2	rim	0.0046	1.7381	0.0074	0.0005	3.0144	86.27	13.50	86.46
38-4-14	1	core	0.0056	1.7603	0.0017	0.0016	3.0156	87.07	12.65	87.32
38-4-15	1	rim	0.0047	1.7444	0.0054	0.0017	3.0155	86.53	13.24	86.73
38-4-19	2	core	0.0055	1.7287	0.0067	0.0006	3.0150	85.77	13.96	86.00
38-4-20	2	rim	0.0050	1.7426	0.0069	0.0004	3.0213	85.89	13.87	86.10
38-4-23	1	core	0.0052	1.7543	0.0013	0.0016	3.0122	87.10	12.64	87.33

Sample	Type	Spot	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	Mno
38-4-5	2	core	0.0093	47.04	0.0677	39.4	0	0.2984	0.0449	0.0481	0.1834
38-4-6	2	rim	0.0731	46.66	0.16	40.23	0.0817	0.2652	0.1201	0.0599	0.198
38-4-9	2	core	0.0376	46.75	0.0998	39.53	0.0099	0.229	0.0637	0.0126	0.2002
38-5-10	1	core	0	48.26	0.0237	39.84	0	0.0794	0.0101	0.0219	0.242
38-5-7	1	rim	0.0148	46.66	0.0441	40.06	0.0283	0.2349	0.0347	0.0018	0.2035
38-5-8	1	core	0.0472	47.98	0.0027	39.86	0.008	0.0559	0.0174	0.005	0.1965
38-5-9	1	rim	0	47.05	0.021	39.69	0.0152	0.2207	0.013	0.077	0.2509
38-6-5	1	rim	0.0371	47.96	0	40.21	0.0181	0.2205	0.0376	0	0.198
38-6-6	1	core	0.0256	48.13	0.0203	39.83	0.0011	0.058	0	0	0.2512
41-2-10	1	core	0.0378	49.48	0.0596	40.36	0.0027	0.0726	0	0.0444	0.145
41-2-11	1	rim	0	49.14	0.0474	40.13	0.0043	0.1582	0.0147	0.1046	0.1864
41-2-7	2	core	0.0731	48.55	0.0586	40.53	0.0043	0.2127	0.0598	0.111	0.2205
41-3-8	1	rim	0.0102	47.57	0.0042	40.52	0	0.2075	0.032	0.033	0.21
41-3-9	1	core	0.0319	49.47	0.0344	40.44	0.0109	0.0997	0.0029	0	0.1775
41-4-3	1	core	0.0127	49.44	0	40.98	0.0027	0.1325	0	0.0432	0.1554
41-4-4	1	rim	0.0469	50.1	0.0114	40.81	0	0.0641	0	0.0172	0.1339

Sample	Type	Spot	FeO	NiO	Tot	Si	Ti	Al	Cr	Fe ²⁺	Ni
38-4-5	2	core	13.02	0.2837	100.40	0.9803	0.0008	0.0020	0.0009	0.2709	0.0057
38-4-6	2	rim	12.79	0.3315	100.97	0.9931	0.0022	0.0047	0.0012	0.2640	0.0066
38-4-9	2	core	12.96	0.3324	100.23	0.9846	0.0012	0.0029	0.0002	0.2699	0.0067
38-5-10	1	core	12.37	0.3918	101.24	0.9797	0.0002	0.0007	0.0004	0.2544	0.0078
38-5-7	1	rim	13.66	0.3083	101.25	0.9896	0.0006	0.0013	0.0000	0.2822	0.0061
38-5-8	1	core	12.74	0.3977	101.31	0.9810	0.0003	0.0001	0.0001	0.2622	0.0079
38-5-9	1	rim	13.68	0.3124	101.33	0.9812	0.0002	0.0006	0.0015	0.2828	0.0062
38-6-5	1	rim	12.66	0.3778	101.72	0.9849	0.0007	0.0000	0.0000	0.2593	0.0074
38-6-6	1	core	12.61	0.3168	101.24	0.9802	0.0000	0.0006	0.0000	0.2595	0.0063
41-2-10	1	core	9.1	0.4026	99.70	0.9916	0.0000	0.0017	0.0009	0.1870	0.0080
41-2-11	1	rim	9.75	0.3394	99.88	0.9878	0.0003	0.0014	0.0020	0.2007	0.0067
41-2-7	2	core	10.89	0.299	101.01	0.9910	0.0011	0.0017	0.0021	0.2227	0.0059
41-3-8	1	rim	12.49	0.2478	101.32	0.9937	0.0006	0.0001	0.0006	0.2562	0.0049
41-3-9	1	core	9.49	0.3464	100.10	0.9912	0.0001	0.0010	0.0000	0.1945	0.0068
41-4-3	1	core	9.47	0.3606	100.60	0.9982	0.0000	0.0000	0.0008	0.1929	0.0071
41-4-4	1	rim	9.76	0.4031	101.35	0.9890	0.0000	0.0003	0.0003	0.1978	0.0079

Sample	Type	Spot	Mn	Mg	Ca	Na	Totale	Fo	Fa	Mg/ (Mg+Fe2+)
38-4-5	2	core	0.0039	1.7447	0.0080	0.0004	3.0176	86.39	13.41	86.56
38-4-6	2	rim	0.0041	1.7171	0.0070	0.0035	3.0035	86.49	13.30	86.67
38-4-9	2	core	0.0042	1.7358	0.0061	0.0018	3.0136	86.36	13.43	86.54
38-5-10	1	core	0.0050	1.7692	0.0021	0.0000	3.0195	87.21	12.54	87.43
38-5-7	1	rim	0.0043	1.7183	0.0062	0.0007	3.0094	85.71	14.08	85.89
38-5-8	1	core	0.0041	1.7603	0.0015	0.0023	3.0197	86.86	12.94	87.04
38-5-9	1	rim	0.0053	1.7339	0.0058	0.0000	3.0175	85.75	13.99	85.98
38-6-5	1	rim	0.0041	1.7513	0.0058	0.0018	3.0153	86.92	12.87	87.10
38-6-6	1	core	0.0052	1.7657	0.0015	0.0012	3.0202	86.96	12.78	87.19
41-2-10	1	core	0.0030	1.8122	0.0019	0.0018	3.0080	90.51	9.34	90.65
41-2-11	1	rim	0.0039	1.8032	0.0042	0.0000	3.0102	89.81	10.00	89.98
41-2-7	2	core	0.0046	1.7697	0.0056	0.0035	3.0077	88.62	11.15	88.82
41-3-8	1	rim	0.0044	1.7391	0.0055	0.0005	3.0056	86.97	12.81	87.16
41-3-9	1	core	0.0037	1.8076	0.0026	0.0015	3.0090	90.12	9.70	90.28
41-4-3	1	core	0.0032	1.7953	0.0035	0.0006	3.0017	90.15	9.69	90.30
41-4-4	1	rim	0.0027	1.8099	0.0017	0.0022	3.0118	90.02	9.84	90.15

Sample	Type	Spot	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	Mno	FeO	Tot
14-1-2	2	Cpx-core	1.5	15.39	5.2	51.4	0	19.59	0.925	1.4147	0.1258	3.92	99.47
14-1-3	2	Cpx-rim	0.6363	13.45	6.83	45.93	0.0163	22.35	4.1	0.0963	0.1078	5.56	99.08
14-2-8	2	Cpx-core	1.44	15.34	6.19	49.93	0.0003	19.68	1.3895	1.69	0.0982	4.01	99.77
14-2-9	2	Cpx-rim	0.7026	11.88	8.63	44.31	0.0056	22.04	4.97	0	0.1303	6.75	99.42
14-3-3	2	Cpx-core	1.0535	14.69	5.5	49.1	0.0156	21.21	1.79	0.9205	0.107	4.88	99.27
14-3-4	2	Cpx-rim	1.0294	14.64	5.69	49.03	0.0005	21.02	1.89	1.55	0.0833	4.71	99.64
18-1-12	2	Cpx-core	0.6069	13.57	6.35	47.67	0.0139	22.12	1.93	0.8753	0.0574	6.02	99.21
18-1-13	2	Cpx-rim	0.7617	12.24	6.67	46.11	0.0108	21.96	3.49	0.0927	0.141	7.31	98.79
18-1-6	2	Cpx-core	1.1402	14.23	6.82	49.65	0.0051	19.56	1.3515	0.4107	0.1274	6.05	99.34
18-1-7	2	Cpx-rim	0.866	9.66	10.53	42.08	0.0189	22.05	5.13	0.1131	0.1481	8.25	98.85
18-2-11	2	Cpx-core	0.9164	10.02	9.88	43.41	0	22.43	4.24	0.0096	0.0859	7.54	98.53
18-2-12	2	Cpx-rim	0.7446	10.5	8.85	44.58	0.0261	22.36	3.89	0.0718	0.0749	7.94	99.04
18-2-15	1	Cpx-core	1.1758	15.05	3.39	52.23	0.006	21.17	0.78	0.2039	0.1385	5.28	99.42
18-2-16	1	Cpx-rim	0.4786	14.17	4.64	49.27	0.0053	22.34	1.6434	0.5179	0.1015	5.91	99.08
18-2-17	1	Cpx-core	0.9712	15.25	3.93	51.33	0	20.55	0.8797	0.4249	0.0977	5.34	98.77
18-2-18	1	Cpx-rim	0.6732	13.07	6.07	47.58	0	22.19	2.58	0.4599	0.0908	6.71	99.42
18-2-5	2	Cpx-core	0.6091	9.33	11.06	41.08	0.0002	22.15	6.11	0.045	0.0726	8.18	98.64
18-2-6	2	Cpx-rim	0.8217	11.98	8.35	45.3	0	22.04	4.42	0.4709	0.0301	5.73	99.14
30-1-13	2	Cpx-core	0.6072	17.62	2.27	53.3	0	20.57	0.1923	1.1808	0.1127	3.52	99.37
30-1-14	2	Cpx-rim	0.7922	14.87	5.22	49.88	0.0161	20.69	1.4873	1.66	0.1124	4.77	99.50
30-1-15	2	Cpx-core	0.7382	15.55	3.73	51.13	0.0014	21.42	0.6782	1.1838	0.0963	4.21	98.74
30-1-16	2	Cpx-rim	0.8951	13.56	5.95	46.31	0.0186	22.11	3.49	0.9852	0.0858	4.27	97.67
30-1-20	1	Opx-core	0.1026	32.91	2.56	56.14	0.0014	1.303	0.0532	0.8153	0.1125	5.48	99.48
30-1-21	1	Opx-rim	0.1229	31.64	3.11	54.99	0	1.8	0.2461	0.496	0.1633	7.46	100.03
30-3-7	2	Cpx-core	0.8186	15.68	2.86	52.04	0.0175	21.59	0.6362	1.55	0.0556	3.87	99.12
30-3-8	2	Cpx-rim	0.9645	13.39	6.4	46.48	0.0228	22.15	4.1	0.9279	0.0628	4.45	98.95
38-1-11	2	Cpx-core	0.904	14.64	7.43	48.03	0.006	20.9	1.5102	2.09	0.1019	4.14	99.75
38-1-12	2	Cpx-rim	0.7867	12.34	9.48	43.95	0.0093	22.44	4.96	0.4339	0.0833	5.15	99.63
38-1-14	1	Cpx-core	0.9013	16.87	2.29	52.3	0	21.43	0.3346	0.8486	0.1407	3.84	98.96
38-1-15	1	Cpx-inter.	0.5043	15.12	4.99	48.52	0.0007	22.39	1.6503	1.0035	0.0214	4.27	98.47
38-1-16	1	Cpx-rim	0.7459	13.71	6.05	46.96	0.014	22.45	3.23	0.5141	0.0745	5.35	99.10
38-1-5	2	Cpx-core	1.37	14.9	7.75	48.61	0.0033	19.84	1.2222	2.06	0.0133	3.78	99.55
38-1-6	2	Cpx-rim	0.8609	13.21	7.09	46.17	0.0379	22.16	4.11	0.6549	0.1203	5.09	99.50
38-2-6	1	Cpx-core	0.7797	16.65	1.97	52.77	0	21.96	0.4516	0.9282	0.0866	3.68	99.28
38-2-7	1	Cpx-rim	0.8753	12.32	9.84	42.6	0.0037	22.16	5.05	0.0989	0.1105	5.21	98.27
38-2-8	1	Cpx-core	0.6806	16.92	1.7196	52.58	0.0044	22.24	0.3003	0.8942	0.1244	3.27	98.73
38-2-9	1	Cpx-rim	0.7868	12.4	10.41	42.85	0.0166	22.24	4.63	0.156	0.0832	5.53	99.10
38-3-1	2	Cpx-core	1.3094	16.1	5.74	50.21	0.0074	19.98	1.0698	1.58	0.0672	3.47	99.53
38-3-2	2	Cpx-rim	0.9953	12.72	7.62	45.34	0.0435	22.07	4.19	0.6843	0.087	5.15	98.90
38-3-3	2	Cpx-core	1.3404	14.87	7.95	49.06	0.2368	18.5	1.2721	1.92	0.0583	4.06	99.27
38-3-4	2	Cpx-rim	0.6757	14.85	6.09	47.65	0.006	21.44	1.68	1.082	0.0236	5.04	98.54
38-4-12	1	Cpx-core	0.7655	16.55	2.33	51.87	0.0105	21.67	0.3762	0.803	0.1612	3.86	98.40
38-4-13	1	Cpx-rim	0.9605	15.34	6.47	48.43	0.0161	20.02	1.3946	1.3636	0.1342	4.3	98.43
38-4-17	2	Cpx-core	0.5582	14.16	6.75	46.89	0	22.26	2.25	1.5	0.1504	4.31	98.83
38-4-18	2	Cpx-rim	0.8201	12.94	8.21	45.02	0.0289	22.03	3.89	0.519	0.0332	4.62	98.11
38-4-21	1	Cpx-core	0.7349	16.78	2.39	52.35	0	21.73	0.4237	0.8103	0.1137	3.98	99.31
38-4-22	1	Cpx-rim	0.7387	15.62	3.35	50.38	0.0053	22.44	1.2342	0.8491	0.0946	3.06	97.77
38-4-3	2	Cpx-core	0.5028	14.44	6.52	46.84	0.0114	22.04	2.18	1.404	0.0501	4.24	98.23
38-4-4	2	Cpx-rim	1.0064	12.49	9.58	43.81	0.0347	22.09	5.06	0.7445	0.0685	4.38	99.26
38-4-7	2	Cpx-core	0.7325	14.88	6.22	48.5	0	21.51	1.94	1.4485	0.0774	4.22	99.53
38-4-8	2	Cpx-rim	0.5656	15.27	5.24	49.13	0.0341	22.1	1.9	1.0325	0.1395	4.24	99.65
38-5-1	2	Cpx-core	0.9307	12.42	9.02	44.33	0.03	22.32	5.12	0.6109	0.1156	4.57	99.47
38-5-2	2	Cpx-rim	0.9646	13.13	7.29	46.2	0.0691	22.13	4.18	0.9519	0.0678	4.08	99.06
38-5-3	2	Cpx-core	0.8819	12.94	8.27	45.12	0.0068	22.15	4.6	1.0216	0.056	4.13	99.18
38-5-4	2	Cpx-rim	0.8673	13.35	7.6	45.99	0.0511	22.03	4.42	0.8817	0.1084	4.2	99.50

Sample	Type	Spot	Si	Ti	Al	Cr	Fe ³⁺	Fe ²⁺	Mn	Mg	Ca	Na
14-1-2	2	Cpx-core	1.8765	0.0254	0.2237	0.0408	0.0379	0.0818	0.0039	0.8376	0.7662	0.1062
14-1-3	2	Cpx-rim	1.7149	0.1152	0.3005	0.0028	0.0834	0.0903	0.0034	0.7486	0.8941	0.0461
14-2-8	2	Cpx-core	1.8191	0.0381	0.2658	0.0487	0.0729	0.0493	0.0030	0.8332	0.7682	0.1017
14-2-9	2	Cpx-rim	1.6616	0.1402	0.3814	0.0000	0.0663	0.1453	0.0041	0.6641	0.8855	0.0511
14-3-3	2	Cpx-core	1.8099	0.0496	0.2389	0.0268	0.0912	0.0592	0.0033	0.8072	0.8377	0.0753
14-3-4	2	Cpx-rim	1.8036	0.0523	0.2467	0.0451	0.0698	0.0751	0.0026	0.8029	0.8285	0.0734
18-1-12	2	Cpx-core	1.8889	0.0020	0.1772	0.0152	0.0359	0.1419	0.0046	1.7000	0.0242	0.0095
18-1-13	2	Cpx-rim	1.8890	0.0022	0.1708	0.0168	0.0360	0.1436	0.0046	1.7054	0.0259	0.0047
18-1-6	2	Cpx-core	1.8478	0.0154	0.2252	0.0471	0.0350	0.0631	0.0018	0.8792	0.8519	0.0337
18-1-7	2	Cpx-rim	1.9025	0.0039	0.2241	0.0328	0.0350	0.0607	0.0046	0.8378	0.7937	0.1042
18-2-11	2	Cpx-core	1.9212	0.0058	0.1390	0.0333	0.0048	0.0881	0.0051	0.9832	0.7884	0.0302
18-2-12	2	Cpx-rim	1.8700	0.0746	0.1707	0.0145	0.0000	0.1190	0.0028	0.7947	0.8868	0.0587
18-2-15	1	Cpx-core	1.9097	0.0066	0.1451	0.0404	0.0333	0.0574	0.0020	0.8684	0.8856	0.0511
18-2-16	1	Cpx-rim	1.9151	0.0063	0.2070	0.0289	0.0304	0.0614	0.0026	0.8494	0.7900	0.1090
18-2-17	1	Cpx-core	1.8808	0.0132	0.1813	0.0268	0.0454	0.0484	0.0029	0.9069	0.8529	0.0414
18-2-18	1	Cpx-rim	1.8798	0.0017	0.1831	0.0147	0.0456	0.1391	0.0034	1.7032	0.0231	0.0061
18-2-5	2	Cpx-core	1.8775	0.0014	0.1794	0.0157	0.0548	0.1256	0.0041	1.7102	0.0234	0.0075
18-2-6	2	Cpx-rim	1.9457	0.0053	0.0977	0.0341	0.0093	0.0981	0.0035	0.9589	0.8045	0.0430
30-1-13	2	Cpx-core	1.8399	0.0413	0.2269	0.0484	0.0197	0.1275	0.0035	0.8177	0.8177	0.0567
30-1-14	2	Cpx-rim	1.8913	0.0189	0.1626	0.0346	0.0355	0.0947	0.0030	0.8575	0.8489	0.0529
30-1-15	2	Cpx-core	1.7470	0.0990	0.2645	0.0294	0.0804	0.0544	0.0027	0.7626	0.8936	0.0655
30-1-16	2	Cpx-rim	1.9461	0.0014	0.1046	0.0223	0.0000	0.1589	0.0033	1.7007	0.0484	0.0069
30-1-20	1	Opx-core	1.9136	0.0064	0.1276	0.0136	0.0270	0.1901	0.0048	1.6414	0.0671	0.0083
30-1-21	1	Opx-rim	1.9183	0.0176	0.1242	0.0452	0.0181	0.1012	0.0017	0.8616	0.8527	0.0585
30-3-7	2	Cpx-core	1.7342	0.1151	0.2814	0.0274	0.0635	0.0754	0.0020	0.7448	0.8855	0.0698
30-3-8	2	Cpx-rim	1.8290	0.0375	0.2961	0.0120	0.0407	0.1457	0.0040	0.7815	0.7720	0.0814
38-1-11	2	Cpx-core	1.6001	0.1468	0.4719	0.0034	0.0957	0.1666	0.0048	0.5476	0.8983	0.0638
38-1-12	2	Cpx-rim	1.7737	0.0540	0.2785	0.0257	0.0848	0.1025	0.0018	0.7527	0.8818	0.0438
38-1-14	1	Cpx-core	1.7372	0.0989	0.2962	0.0028	0.0849	0.1454	0.0045	0.6875	0.8865	0.0556
38-1-15	1	Cpx-inter.	1.5729	0.1760	0.4991	0.0014	0.0470	0.2149	0.0024	0.5325	0.9086	0.0452
38-1-16	1	Cpx-rim	1.6979	0.1246	0.3688	0.0140	0.0319	0.1477	0.0010	0.6694	0.8851	0.0597
38-1-5	2	Cpx-core	1.6478	0.1211	0.4420	0.0003	0.0874	0.1520	0.0028	0.5670	0.9122	0.0674
38-1-6	2	Cpx-rim	1.6857	0.1107	0.3944	0.0021	0.0666	0.1845	0.0024	0.5919	0.9059	0.0546
38-2-6	1	Cpx-core	1.9183	0.0216	0.1467	0.0059	0.0517	0.1104	0.0043	0.8240	0.8330	0.0837
38-2-7	1	Cpx-rim	1.8349	0.0460	0.2037	0.0152	0.0540	0.1300	0.0032	0.7867	0.8914	0.0346
38-2-8	1	Cpx-core	1.8986	0.0245	0.1713	0.0124	0.0397	0.1254	0.0031	0.8409	0.8144	0.0696
38-2-9	1	Cpx-rim	1.7739	0.0724	0.2667	0.0136	0.0759	0.1333	0.0029	0.7264	0.8864	0.0487
38-3-1	2	Cpx-core	1.7742	0.0336	0.3334	0.0594	0.0888	0.0266	0.0004	0.8107	0.7758	0.0969
38-3-2	2	Cpx-rim	1.7156	0.1149	0.3105	0.0192	0.0731	0.0851	0.0038	0.7318	0.8822	0.0620
38-3-3	2	Cpx-core	1.7609	0.0417	0.3211	0.0606	0.0777	0.0492	0.0032	0.8002	0.8210	0.0643
38-3-4	2	Cpx-rim	1.6346	0.1388	0.4155	0.0128	0.0822	0.0780	0.0026	0.6842	0.8942	0.0567
38-4-12	1	Cpx-core	1.9173	0.0092	0.0989	0.0246	0.0874	0.0304	0.0044	0.9220	0.8417	0.0641
38-4-13	1	Cpx-rim	1.8048	0.0462	0.2188	0.0295	0.0861	0.0467	0.0007	0.8385	0.8923	0.0364
38-4-17	2	Cpx-core	1.7487	0.0905	0.2655	0.0151	0.0956	0.0710	0.0023	0.7611	0.8957	0.0539
38-4-18	2	Cpx-rim	1.9334	0.0124	0.0851	0.0269	0.0518	0.0609	0.0027	0.9094	0.8620	0.0554
38-4-21	1	Cpx-core	1.6025	0.1429	0.4362	0.0029	0.1341	0.0298	0.0035	0.6909	0.8931	0.0638
38-4-22	1	Cpx-rim	1.9339	0.0083	0.0745	0.0260	0.0639	0.0367	0.0039	0.9277	0.8764	0.0485
38-4-3	2	Cpx-core	1.5977	0.1299	0.4575	0.0046	0.1405	0.0319	0.0026	0.6892	0.8884	0.0569
38-4-4	2	Cpx-rim	1.8267	0.0293	0.2461	0.0454	0.0891	0.0165	0.0021	0.8732	0.7788	0.0924
38-4-7	2	Cpx-core	1.6951	0.1179	0.3358	0.0202	0.0923	0.0688	0.0028	0.7090	0.8841	0.0721
38-4-8	2	Cpx-rim	1.7964	0.0350	0.3431	0.0556	0.0446	0.0797	0.0018	0.8117	0.7258	0.0952
38-5-1	2	Cpx-core	1.7712	0.0470	0.2668	0.0318	0.1139	0.0427	0.0007	0.8229	0.8539	0.0487
38-5-2	2	Cpx-rim	1.7511	0.0613	0.2873	0.0415	0.0833	0.0493	0.0016	0.8048	0.8828	0.0364
38-5-3	2	Cpx-core	1.6301	0.1416	0.4201	0.0219	0.0887	0.0476	0.0022	0.6928	0.8807	0.0726
38-5-4	2	Cpx-rim	1.7851	0.0537	0.2698	0.0422	0.0627	0.0672	0.0024	0.8164	0.8482	0.0523

Sample	Type	Spot	Tot	Wo	En	Fs	Mg/ (Mg+Fe2+)
14-1-2	2	Cpx-core	4.0000	41.88	45.78	6.54	87.50
14-1-3	2	Cpx-rim	3.9992	48.01	40.20	9.32	81.18
14-2-8	2	Cpx-core	4.0000	42.09	45.65	6.69	87.21
14-2-9	2	Cpx-rim	3.9997	48.86	36.64	11.68	75.83
14-3-3	2	Cpx-core	3.9993	44.78	43.15	8.04	84.29
14-3-4	2	Cpx-rim	4.0000	44.79	43.41	7.83	84.71
18-1-12	2	Cpx-core	3.9994	1.26	88.94	9.30	90.53
18-1-13	2	Cpx-rim	3.9988	1.35	89.03	9.38	90.47
18-1-6	2	Cpx-core	4.0000	45.73	47.20	5.26	89.97
18-1-7	2	Cpx-rim	3.9994	43.34	45.75	5.23	89.75
18-2-11	2	Cpx-core	3.9990	41.61	51.89	4.90	91.37
18-2-12	2	Cpx-rim	3.9918	47.70	42.74	6.40	86.98
18-2-15	1	Cpx-core	3.9997	46.71	45.81	4.78	90.55
18-2-16	1	Cpx-rim	4.0000	42.93	46.16	4.99	90.24
18-2-17	1	Cpx-core	4.0000	45.01	47.86	4.95	90.62
18-2-18	1	Cpx-rim	3.9998	1.21	88.84	9.63	90.22
18-2-5	2	Cpx-core	3.9997	1.22	89.00	9.39	90.46
18-2-6	2	Cpx-rim	4.0000	42.04	50.10	5.61	89.92
30-1-13	2	Cpx-core	3.9992	44.46	44.46	8.00	84.75
30-1-14	2	Cpx-rim	3.9999	44.93	45.38	6.89	86.81
30-1-15	2	Cpx-core	3.9991	48.14	41.08	7.26	84.99
30-1-16	2	Cpx-rim	3.9925	2.53	88.82	8.30	91.46
30-1-20	1	Opx-core	4.0000	3.47	84.87	11.23	88.32
30-1-21	1	Opx-rim	3.9992	45.06	45.54	6.31	87.84
30-3-7	2	Cpx-core	3.9989	48.15	40.50	7.55	84.29
30-3-8	2	Cpx-rim	3.9998	42.39	42.91	10.23	80.74
38-1-11	2	Cpx-core	3.9991	50.69	30.90	14.80	67.61
38-1-12	2	Cpx-rim	3.9993	47.27	40.35	10.04	80.07
38-1-14	1	Cpx-core	3.9995	47.66	36.96	12.38	74.90
38-1-15	1	Cpx-inter.	4.0000	51.97	30.46	14.98	67.03
38-1-16	1	Cpx-rim	4.0000	49.34	37.32	10.01	78.84
38-1-5	2	Cpx-core	4.0000	51.08	31.75	13.40	70.32
38-1-6	2	Cpx-rim	3.9987	50.23	32.82	13.92	70.21
38-2-6	1	Cpx-core	3.9997	43.78	43.30	8.52	83.56
38-2-7	1	Cpx-rim	3.9997	47.00	41.48	9.70	81.04
38-2-8	1	Cpx-core	4.0000	43.09	44.49	8.74	83.58
38-2-9	1	Cpx-rim	4.0000	47.38	38.83	11.18	77.64
38-3-1	2	Cpx-core	3.9998	43.13	45.07	6.41	87.54
38-3-2	2	Cpx-rim	3.9982	48.10	39.90	8.62	82.23
38-3-3	2	Cpx-core	3.9997	45.30	44.15	7.00	86.31
38-3-4	2	Cpx-rim	3.9996	49.81	38.11	8.92	81.03
38-4-12	1	Cpx-core	4.0000	43.27	47.39	6.05	88.68
38-4-13	1	Cpx-rim	4.0000	46.97	44.13	6.99	86.32
38-4-17	2	Cpx-core	3.9993	47.71	40.54	8.88	82.04
38-4-18	2	Cpx-rim	4.0000	44.44	46.89	5.81	88.97
38-4-21	1	Cpx-core	3.9998	49.30	38.13	9.05	80.83
38-4-22	1	Cpx-rim	3.9998	44.87	47.50	5.15	90.22
38-4-3	2	Cpx-core	3.9992	49.17	38.14	9.54	79.99
38-4-4	2	Cpx-rim	3.9997	42.10	47.20	5.71	89.21
38-4-7	2	Cpx-core	3.9979	48.41	38.82	8.82	81.49
38-4-8	2	Cpx-rim	3.9889	41.31	46.20	7.08	86.72
38-5-1	2	Cpx-core	3.9997	45.37	43.72	8.32	84.01
38-5-2	2	Cpx-rim	3.9995	47.55	43.35	7.14	85.86
38-5-3	2	Cpx-core	3.9984	49.41	38.87	7.65	83.56
38-5-4	2	Cpx-rim	4.0000	45.93	44.21	7.03	86.27

Sample	Type	Spot	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	Mno	FeO	Tot
38-6-1	1	Cpx-core	0.7895	16.7	2.1	52.13	0.0055	21.76	0.3523	0.8066	0.1101	3.73	98.48
38-6-2	1	Cpx-rim	0.6729	17.3	1.8248	52.92	0.0034	21.88	0.3061	0.8659	0.0925	3.5	99.37
38-6-3	1	Opx-rim	0.0567	34.01	1.5448	55.83	0.0036	0.7467	0.0646	0.281	0.2319	7.55	100.32
38-6-4	1	Opx-core	0.181	33.64	1.5161	55.73	0	0.7094	0.1437	0.2676	0.198	7.7	100.09
41-2-1	1	Opx-core	0.143	33.15	4.37	54.91	0.0138	0.6556	0.0781	0.5585	0.1582	6.18	100.22
41-2-14	1	Cpx-core	1.47	15.37	5.2	52.03	0.0126	20.26	0.1429	1.1337	0.147	3.13	98.90
41-2-15	1	Cpx-rim	0.4262	18.06	3.23	52.61	0.0215	20.15	0.2121	1.153	0.1635	3.04	99.07
41-2-2	1	Opx-rim	0.0701	33.4	4.23	55.15	0.0274	0.7045	0.084	0.6208	0.1582	6.27	100.72
41-2-8	2	Cpx-core	0.4725	16.05	5.2	50.29	0	21.64	0.5564	1.62	0.0564	3.19	99.08
41-3-12	1	Cpx-core	1.53	15.51	4.78	52.13	0	20.07	0.2271	0.9947	0.0832	2.99	98.32
41-3-13	1	Cpx-rim	0.5858	16.69	4.22	51.6	0	21.84	0.4801	0.93	0.0943	3.08	99.52
41-3-3	2	Cpx-rim	0.8156	14.35	3.9	50.34	0.0142	22.28	2.67	0.4927	0.0889	3.83	98.78
41-3-4	2	Cpx-core	0.7177	15.85	3.35	51.96	0.0057	22.49	0.2379	1.3901	0.0653	2.95	99.02
41-4-1	1	Opx-core	0.0917	33.16	4.51	54.56	0.0045	0.6265	0.0648	0.5396	0.1161	6.41	100.08
41-4-2	1	Opx-rim	0.1134	33.46	4.44	54.76	0.0072	0.6373	0.056	0.5785	0.1396	6.29	100.48

Sample	Type	Spot	Si	Ti	Al	Cr	Fe ³⁺	Fe ²⁺	Mn	Mg	Ca	Na
38-6-1	1	Cpx-core	1.8063	0.0526	0.2271	0.0300	0.0672	0.0632	0.0043	0.8369	0.8705	0.0403
38-6-2	1	Cpx-rim	1.9160	0.0105	0.1014	0.0235	0.0774	0.0418	0.0050	0.9114	0.8576	0.0548
38-6-3	1	Opx-rim	1.7922	0.0388	0.2822	0.0399	0.0856	0.0474	0.0042	0.8462	0.7937	0.0689
38-6-4	1	Opx-core	1.7448	0.0630	0.2960	0.0441	0.0846	0.0496	0.0047	0.7855	0.8875	0.0403
41-2-1	1	Opx-core	1.6918	0.1100	0.3636	0.0154	0.0786	0.0665	0.0011	0.7249	0.8870	0.0598
41-2-14	1	Cpx-core	1.9163	0.0117	0.1031	0.0235	0.0696	0.0522	0.0035	0.9157	0.8522	0.0522
41-2-15	1	Cpx-rim	1.8775	0.0346	0.1471	0.0250	0.0573	0.0381	0.0030	0.8678	0.8960	0.0534
41-2-2	1	Opx-rim	1.9224	0.0098	0.0913	0.0235	0.0775	0.0375	0.0034	0.9181	0.8598	0.0564
41-2-8	2	Cpx-core	1.9326	0.0084	0.0785	0.0250	0.0623	0.0446	0.0029	0.9418	0.8561	0.0476
41-3-12	1	Cpx-core	1.9244	0.0017	0.0628	0.0077	0.0814	0.1362	0.0068	1.7476	0.0276	0.0038
41-3-13	1	Cpx-rim	1.9266	0.0037	0.0618	0.0073	0.0823	0.1403	0.0058	1.7337	0.0263	0.0121
41-3-3	2	Cpx-rim	1.6497	0.1433	0.3956	0.0180	0.0689	0.0733	0.0036	0.6890	0.8899	0.0672
41-3-4	2	Cpx-core	1.7207	0.1171	0.3200	0.0280	0.0494	0.0777	0.0021	0.7290	0.8831	0.0697
41-4-1	1	Opx-core	1.6808	0.1289	0.3631	0.0301	0.0514	0.0773	0.0018	0.7186	0.8841	0.0637
41-4-2	1	Opx-rim	1.7061	0.1234	0.3323	0.0259	0.0478	0.0825	0.0034	0.7383	0.8756	0.0624

Sample	Type	Spot	Tot	Wo	En	Fs	Mg/ (Mg+Fe ²⁺)
38-6-1	1	Cpx-core	3.9984	46.35	44.56	6.94	86.52
38-6-2	1	Cpx-rim	3.9995	44.14	46.90	6.14	88.43
38-6-3	1	Opx-rim	3.9992	43.09	45.94	7.22	86.41
38-6-4	1	Opx-core	4.0000	48.04	42.52	7.26	85.42
41-2-1	1	Opx-core	3.9986	48.82	39.90	7.99	83.31
41-2-14	1	Cpx-core	4.0000	43.89	47.15	6.27	88.26
41-2-15	1	Cpx-rim	3.9997	46.85	45.37	4.99	90.10
41-2-2	1	Opx-rim	3.9997	44.11	47.10	5.90	88.87
41-2-8	2	Cpx-core	3.9998	43.85	48.24	5.47	89.81
41-3-12	1	Cpx-core	3.9998	1.38	87.53	10.90	88.93
41-3-13	1	Cpx-rim	4.0000	1.32	86.91	11.16	88.62
41-3-3	2	Cpx-rim	3.9986	49.76	38.53	7.95	82.89
41-3-4	2	Cpx-core	3.9967	48.82	40.30	7.03	85.16
41-4-1	1	Opx-core	3.9997	49.25	40.03	7.17	84.81
41-4-2	1	Opx-rim	3.9976	48.47	40.87	7.21	85.00

Sample	Type	Spot	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	Mno	FeO
18-1-1	2	trav: pl-rim	6.24	0.002	26.97	57.29	0.7085	7.95	0.1709	0	0	0.2736
18-1-2	2	trav: pl	5.48	0.0341	28.37	55.82	0.5265	9.57	0.1455	0	0	0.3104
18-1-3	2	trav: pl	5.08	0.042	29.14	54.26	0.4483	10.36	0.1949	0.0068	0.0008	0.3078
18-1-4	2	trav: pl	5.21	0.0489	28.97	55.04	0.45	10.26	0.1392	0	0	0.3295
18-1-5	2	trav: pl-core	5.18	0.0578	28.84	54.39	0.4517	10.07	0.1989	0	0	0.2828
18-2-1	2	core	5.4	0.0579	27.87	54	0.5387	9.38	0.1928	0.0056	0	0.332
18-2-2	2	rim	6.18	0.0261	27.23	57.03	0.6915	8.18	0.2076	0.0407	0.0511	0.2618
18-2-3	2	core	5.99	0.013	26.82	56.88	0.6936	7.81	0.3554	0	0.0392	0.3207
18-2-4	2	rim	6.13	0.02	26.95	57.16	0.691	8.24	0.1494	0	0	0.2775
30-1-10	2	rim	7.09	0.0314	25.29	58.33	1.1322	5.96	0.2426	0.0231	0.0275	0.2923
30-1-7	2	core	6.05	0.0302	27.44	56.27	0.683	8.75	0.1965	0	0.032	0.2345
30-1-8	2	rim	7.25	0.0283	25.49	59.17	1.1285	6.34	0.2682	0.0108	0.0156	0.23
30-1-9	2	core	6.07	0.0442	27.14	56.44	0.6686	8.24	0.2475	0.0054	0	0.244
30-3-1	2	core	6.27	0.0251	27.29	57.24	0.7023	8.19	0.2234	0.0005	0	0.211
30-3-2	2	rim	6.82	0.0354	26.21	57.63	0.9073	7.1	0.2592	0.0654	0	0.2218
30-3-3	2	core	5.72	0.0442	27.86	55.99	0.6148	8.93	0.2056	0.0075	0	0.2962
30-3-4	2	rim	5.68	0.0583	27.47	56.01	0.5914	9.05	0.1574	0.0035	0.0082	0.451
38-1-10	2	rim	5.3	0	28.92	54.38	0.4633	10.07	0.2533	0.0033	0	0.3278
38-1-9	2	core	5.25	0.0401	29.5	54.01	0.4465	10.39	0.1529	0	0	0.3857
38-3-11	2	trav: pl-core	5.72	0.0391	28.5	53.07	0.5466	9.48	0.1691	0.0162	0.0022	0.231
38-3-12	2	trav: pl	5.64	0.044	28.48	53.1	0.545	9.26	0.2394	0.0404	0.003	0.222
38-3-13	2	trav: pl	5.61	0.0591	28.49	54.11	0.5598	9.36	0.1765	0.0638	0.023	0.2877
38-3-14	2	trav: pl	5.61	0.039	28.48	54.97	0.5533	9.47	0.2095	0.0332	0.0348	0.2664
38-3-15	2	trav: pl	5.28	0.042	29.19	53.71	0.4731	10.1	0.2186	0.0056	0.0341	0.2978
38-3-16	2	trav: pl-rim	6.99	0.0434	26.71	56.4	0.7376	7.16	0.3673	0.0165	0.0089	0.2946
41-2-12	2	core	6.39	0.9726	26.56	57.37	0.8408	7.23	0.2631	0	0.0385	0.3612
41-2-13	2	core	7.71	0.0051	23.18	61.99	2.55	3.66	0.2881	0	0.0075	0.1642
41-3-1	2	core	6.42	0	26.92	57.25	0.7476	8.05	0.2657	0	0	0.2864
41-3-2	2	core	6.08	0.0262	27.72	55.83	0.5763	8.85	0.2238	0	0.0424	0.3424

Sample	Type	Spot	Tot	Si	Ti	Al	Cr	Fe ³⁺	Mn	Mg	Ca	Na
18-1-1	2	trav: pl-rim	99.61	2.5765	0.0058	1.4295	0.0000	0.0103	0.0000	0.0001	0.3831	0.5441
18-1-2	2	trav: pl	100.26	2.5038	0.0049	1.4997	0.0000	0.0117	0.0000	0.0023	0.4599	0.4766
18-1-3	2	trav: pl	99.84	2.4511	0.0066	1.5514	0.0002	0.0116	0.0000	0.0028	0.5014	0.4449
18-1-4	2	trav: pl	100.45	2.4692	0.0047	1.5318	0.0000	0.0124	0.0000	0.0033	0.4932	0.4532
18-1-5	2	trav: pl-core	99.47	2.4638	0.0068	1.5397	0.0000	0.0107	0.0000	0.0039	0.4887	0.4550
18-2-1	2	core	97.78	2.4871	0.0067	1.5128	0.0002	0.0128	0.0000	0.0040	0.4629	0.4822
18-2-2	2	rim	99.90	2.5607	0.0070	1.4410	0.0014	0.0098	0.0019	0.0017	0.3935	0.5380
18-2-3	2	core	98.92	2.5740	0.0121	1.4304	0.0000	0.0122	0.0015	0.0009	0.3787	0.5256
18-2-4	2	rim	99.62	2.5722	0.0051	1.4293	0.0000	0.0105	0.0000	0.0013	0.3973	0.5348
30-1-10	2	rim	98.42	2.6487	0.0083	1.3534	0.0008	0.0111	0.0011	0.0021	0.2900	0.6242
30-1-7	2	core	99.69	2.5377	0.0067	1.4585	0.0000	0.0089	0.0012	0.0020	0.4228	0.5290
30-1-8	2	rim	99.93	2.6488	0.0090	1.3449	0.0004	0.0086	0.0006	0.0019	0.3041	0.6293
30-1-9	2	core	99.10	2.5546	0.0084	1.4478	0.0002	0.0093	0.0000	0.0030	0.3996	0.5327
30-3-1	2	core	100.15	2.5630	0.0075	1.4402	0.0000	0.0079	0.0000	0.0017	0.3929	0.5443
30-3-2	2	rim	99.25	2.6019	0.0088	1.3947	0.0023	0.0084	0.0000	0.0024	0.3434	0.5970
30-3-3	2	core	99.67	2.5236	0.0070	1.4799	0.0003	0.0112	0.0000	0.0030	0.4312	0.4999
30-3-4	2	rim	99.48	2.5306	0.0053	1.4628	0.0001	0.0171	0.0003	0.0039	0.4381	0.4976
38-1-10	2	rim	99.72	2.4592	0.0086	1.5414	0.0001	0.0124	0.0000	0.0000	0.4879	0.4647
38-1-9	2	core	100.18	2.4349	0.0052	1.5674	0.0000	0.0146	0.0000	0.0027	0.5019	0.4589
38-3-11	2	trav: pl-core	97.77	2.4513	0.0059	1.5515	0.0006	0.0089	0.0001	0.0027	0.4691	0.5123
38-3-12	2	trav: pl	97.57	2.4549	0.0083	1.5518	0.0015	0.0086	0.0001	0.0030	0.4587	0.5056
38-3-13	2	trav: pl	98.74	2.4705	0.0061	1.5330	0.0023	0.0110	0.0009	0.0040	0.4579	0.4966
38-3-14	2	trav: pl	99.67	2.4845	0.0071	1.5171	0.0012	0.0101	0.0013	0.0026	0.4586	0.4916
38-3-15	2	trav: pl	99.35	2.4404	0.0075	1.5632	0.0002	0.0113	0.0013	0.0028	0.4917	0.4652
38-3-16	2	trav: pl-rim	98.73	2.5643	0.0126	1.4313	0.0006	0.0112	0.0003	0.0029	0.3488	0.6162
41-2-12	2	core	100.03	2.5711	0.0089	1.4029	0.0000	0.0136	0.0015	0.0650	0.3472	0.5553
41-2-13	2	core	99.55	2.7762	0.0097	1.2235	0.0000	0.0062	0.0003	0.0003	0.1756	0.6695
41-3-1	2	core	99.94	2.5705	0.0090	1.4245	0.0000	0.0108	0.0000	0.0000	0.3873	0.5589
41-3-2	2	core	99.69	2.5198	0.0076	1.4745	0.0000	0.0129	0.0016	0.0018	0.4280	0.5320

Sample	Type	Spot	K	Tot	Ab %	An %	Or %
18-1-1	2	trav: pl-rim	0.0406	4.9901	56.22	39.58	4.20
18-1-2	2	trav: pl	0.0301	4.9890	49.30	47.58	3.12
18-1-3	2	trav: pl	0.0258	4.9960	45.77	51.58	2.66
18-1-4	2	trav: pl	0.0258	4.9935	46.62	50.73	2.65
18-1-5	2	trav: pl-core	0.0261	4.9947	46.91	50.40	2.69
18-2-1	2	core	0.0317	5.0003	49.37	47.39	3.24
18-2-2	2	rim	0.0396	4.9949	55.40	40.52	4.08
18-2-3	2	core	0.0400	4.9754	55.66	40.10	4.24
18-2-4	2	rim	0.0397	4.9901	55.04	40.88	4.08
30-1-10	2	rim	0.0656	5.0053	63.71	29.60	6.69
30-1-7	2	core	0.0393	5.0061	53.38	42.66	3.96
30-1-8	2	rim	0.0644	5.0120	63.07	30.48	6.46
30-1-9	2	core	0.0386	4.9941	54.87	41.16	3.98
30-3-1	2	core	0.0401	4.9977	55.69	40.20	4.10
30-3-2	2	rim	0.0523	5.0112	60.14	34.60	5.26
30-3-3	2	core	0.0354	4.9914	51.72	44.62	3.66
30-3-4	2	rim	0.0341	4.9899	51.31	45.18	3.52
38-1-10	2	rim	0.0267	5.0010	47.45	49.82	2.73
38-1-9	2	core	0.0257	5.0112	46.52	50.88	2.60
38-3-11	2	trav: pl-core	0.0322	5.0346	50.54	46.28	3.18
38-3-12	2	trav: pl	0.0321	5.0247	50.74	46.03	3.23
38-3-13	2	trav: pl	0.0326	5.0149	50.31	46.39	3.30
38-3-14	2	trav: pl	0.0319	5.0060	50.06	46.69	3.25
38-3-15	2	trav: pl	0.0274	5.0110	47.26	49.96	2.79
38-3-16	2	trav: pl-rim	0.0428	5.0310	61.14	34.61	4.25
41-2-12	2	core	0.0481	5.0134	58.42	36.53	5.06
41-2-13	2	core	0.1457	5.0069	67.57	17.73	14.70
41-3-1	2	core	0.0428	5.0037	56.51	39.16	4.33
41-3-2	2	core	0.0332	5.0115	53.57	43.09	3.34

Sample	Type	Spot	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Cr ₂ O ₃
14-1-4	1	amph.	39.98	8.91	12.74	5.75	0.0294	14.2	11.98	2.68	0.9576	0.0261	0.9532
14-2-10	1	apatite	0.3147	0.0092	0.0683	0.1423	0.0274	0.2368	54.41	0.1187	0.0656	42.3	0
30-3-14	1	apatite	0.3481	0	0.0217	0.1767	0.0341	0.2025	53.89	0.1355	0.1099	43.47	0.0045
38-1-17	1	apatite	0.3513	0	0	0.3566	0	0.2099	53.91	0.1032	0.0318	42.88	0
38-3-17	1	apatite	0.2645	0.0522	0.023	0.2606	0.0015	0.2061	53.98	0.107	0.0462	43.67	0.0126
38-3-9	1	apatite	3.97	0.1671	1.2533	0.4785	0.0252	0.2097	49.91	0.9811	0.1651	39.74	0
38-4-11	1	apatite	0.5798	0.0184	0.0635	0.3296	0.0214	0.1783	52.89	0.0811	0.1016	42.87	0
41-2-9	1	apatite	0.4714	0	0.0086	0.1794	0.0178	0.2665	52.39	0.244	0.0362	42.67	0.0163
41-3-7	1	apatite	0.321	0.0185	0.0016	0.238	0.0059	0.2079	52.78	0.1145	0.0832	42.93	0

Sample	Type	Spot	NiO	Tot
14-1-4	1	amph.	0.1061	98.31
14-2-10	1	apatite	0.036	97.73
30-3-14	1	apatite	0.0972	98.49
38-1-17	1	apatite	0	97.84
38-3-17	1	apatite	0	98.62
38-3-9	1	apatite	0	96.90
38-4-11	1	apatite	0	97.13
41-2-9	1	apatite	0.0316	96.33
41-3-7	1	apatite	0.0102	96.71

Sample	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
14-2-VTR-3	55.91	0.94	21.83	1.15	0.03	0.18	1.24	7.33	8.57	0.30
14-2-VTR-4	55.52	0.78	21.76	1.09	0.01	0.19	1.31	6.52	9.63	0.36
14-2-VTR-5	56.19	0.90	21.50	1.13	0.04	0.12	1.08	6.76	8.96	0.37
18-1-VTR-1	52.43	1.75	23.27	2.47	0.05	0.33	0.97	7.13	9.90	0.44
18-1-VTR-2	51.85	1.57	23.34	2.64	0.05	0.51	1.23	6.98	9.31	0.40
18-1-VTR-3	51.89	1.74	22.82	2.49	0.00	0.53	1.08	6.86	9.67	0.36
18-2-VTR-1	51.91	1.82	22.62	2.64	0.00	0.61	1.22	7.23	9.42	0.53
18-2-VTR-2	52.32	1.62	23.28	2.36	0.05	0.36	0.90	7.09	9.61	0.40
18-2-VTR-3	52.46	1.66	23.29	1.94	0.05	0.28	0.86	7.35	9.35	0.57
30-1-VTR-1	53.55	2.00	22.45	2.11	0.03	1.04	1.10	8.26	7.09	0.53
30-1-VTR-2	54.02	2.09	22.86	2.00	0.02	1.01	1.06	8.59	6.33	0.35
30-1-VTR-3	53.70	2.22	22.48	2.07	0.03	0.96	0.88	8.71	6.40	0.59
30-1-VTR-4	54.45	2.20	23.04	2.20	0.03	0.78	0.71	8.25	6.65	0.41
30-3-VTR-1	53.18	2.05	22.77	2.52	0.00	1.03	1.32	8.41	6.85	0.39
30-3-VTR-2	53.73	1.94	22.85	2.26	0.01	1.04	1.38	8.84	7.08	0.56
30-3-VTR-3	53.37	1.88	22.64	2.24	0.00	0.98	1.19	8.22	7.74	0.45
38-1-VTR-1	51.85	1.64	24.00	2.18	0.02	0.85	1.30	7.41	7.67	0.38
38-1-VTR-2	50.93	1.93	23.51	2.44	0.03	1.03	1.56	7.65	7.37	0.54
38-1-VTR-3	50.91	1.87	23.33	2.54	0.00	0.94	1.35	7.82	8.44	0.39
38-1-VTR-4	50.49	2.00	23.45	2.56	0.00	1.06	1.58	7.26	8.62	0.42
38-2-VTR-1	51.66	2.09	23.80	2.02	0.02	1.17	1.62	5.68	6.42	0.74
38-2-VTR-2	51.18	2.13	24.15	2.01	0.04	1.12	1.66	8.09	6.31	0.59
38-2-VTR-3	50.56	2.19	24.32	1.95	0.00	1.03	1.56	8.16	6.44	0.40
38-2-VTR-4	51.95	2.13	23.50	1.96	0.02	1.22	1.63	5.22	6.53	0.55
38-3-VTR-1	51.56	1.74	23.46	2.61	0.05	1.01	1.31	7.74	8.15	0.48
38-3-VTR-2	51.54	1.84	23.33	2.57	0.01	1.27	1.18	4.32	6.47	0.53
38-3-VTR-3	51.36	1.72	23.56	2.65	0.00	0.83	1.22	6.47	7.59	0.34
38-4-VTR-1	51.53	1.93	24.89	1.87	0.05	0.76	1.22	7.82	6.69	0.42
38-4-VTR-2	51.19	2.03	24.22	1.82	0.04	0.90	1.60	7.77	6.95	0.40
38-4-VTR-3	51.97	1.82	24.38	1.75	0.01	0.71	1.22	6.79	6.54	0.45
38-5-VTR-1	51.84	1.99	24.07	2.16	0.00	0.80	1.15	5.55	6.85	0.28
38-5-VTR-2	52.27	1.99	24.12	2.10	0.07	0.83	1.12	5.25	6.86	0.52
38-5-VTR-3	51.97	1.98	23.81	2.12	0.05	0.82	1.19	5.16	6.94	0.34
41-2-VTR-1	59.69	0.28	25.38	0.23	0.02	0.02	6.22	7.22	1.18	0.00
41-2-VTR-2	58.54	0.28	26.13	0.14	0.00	0.02	6.94	6.97	0.99	0.03
41-2-VTR-3	59.47	0.30	25.62	0.25	0.02	0.16	6.76	7.17	1.10	0.02
41-3-VTR-1	59.93	0.82	19.46	1.07	0.05	2.26	1.01	2.94	9.80	0.03
41-3-VTR-2	59.71	1.12	19.07	0.91	0.02	1.72	0.95	1.94	11.99	0.18

Sample	Cr ₂ O ₃	NiO	Tot
14-2-VTR-3	0.00	0.00	97.49
14-2-VTR-4	0.00	0.02	97.18
14-2-VTR-5	0.00	0.00	97.05
18-1-VTR-1	0.00	0.01	98.75
18-1-VTR-2	0.07	0.06	98.02
18-1-VTR-3	0.02	0.00	97.46
18-2-VTR-1	0.00	0.03	98.02
18-2-VTR-2	0.00	0.02	98.01
18-2-VTR-3	0.00	0.00	97.81
30-1-VTR-1	0.00	0.00	98.16
30-1-VTR-2	0.01	0.02	98.36
30-1-VTR-3	0.04	0.00	98.08
30-1-VTR-4	0.01	0.04	98.78
30-3-VTR-1	0.04	0.00	98.57
30-3-VTR-2	0.00	0.00	99.69
30-3-VTR-3	0.01	0.00	98.72
38-1-VTR-1	0.00	0.01	97.32
38-1-VTR-2	0.00	0.00	96.98
38-1-VTR-3	0.07	0.04	97.69
38-1-VTR-4	0.00	0.00	97.44
38-2-VTR-1	0.02	0.00	95.24
38-2-VTR-2	0.00	0.04	97.31
38-2-VTR-3	0.00	0.00	96.61
38-2-VTR-4	0.00	0.00	94.70
38-3-VTR-1	0.00	0.00	98.11
38-3-VTR-2	0.00	0.00	93.05
38-3-VTR-3	0.01	0.00	95.75
38-4-VTR-1	0.00	0.00	97.18
38-4-VTR-2	0.01	0.03	96.96
38-4-VTR-3	0.04	0.01	95.69
38-5-VTR-1	0.01	0.05	94.75
38-5-VTR-2	0.00	0.07	95.19
38-5-VTR-3	0.00	0.06	94.43
41-2-VTR-1	0.02	0.01	100.26
41-2-VTR-2	0.03	0.01	100.09
41-2-VTR-3	0.05	0.00	100.92
41-3-VTR-1	0.00	0.02	97.39
41-3-VTR-2	0.05	0.02	97.68

Sample	Type	Spot	Li7_ppm	Be9_ppm	Na23_ppm	Al27_ppm	Si29_ppm	K39_ppm	Ca42_ppm	Sc45_ppm	Ti47_ppm	V51_ppm	Cr53_ppm	Mn55_ppm	Co59_ppm
14-1-5	2	sp-core	<LOD	<LOD	<LOD	186391	<LOD	<LOD	<LOD	1	13452	1277	218626	1801	253
14-1-6	2	sp-rim	3	<LOD	443	148075	<LOD	168	218	2	32333	1661	159023	1830	235
14-2-11	2	sp	10	<LOD	776	122102	<LOD	342	<LOD	<LOD	61823	2423	168308	3061	294
14-3-1	2	sp	<LOD	<LOD	<LOD	91475	<LOD	<LOD	<LOD	3	33175	1735	315588	2544	288
14-3-2	2	sp	5	<LOD	92	127999	<LOD	157	<LOD	3	38353	1733	233712	2403	268
18-1-11	2	sp	11	<LOD	130	43950	<LOD	124	<LOD	4	138065	3063	60055	3366	354
18-2-14	2	sp	12	0.7	2653	43093	22620	3754	2264	6	126401	2601	57117	2864	338
30-3-11	1	sp-rim	5	<LOD	<LOD	85232	<LOD	<LOD	<LOD	4	62990	1809	205793	2849	270
30-3-12	1	sp-core	6	0.6	448	151522	18663	506	<LOD	7	19199	840	210986	2006	250
30-3-13	1	sp-core	<LOD	<LOD	432	210838	<LOD	115	<LOD	3	3467	606	221358	1760	264
38-2-12	2	sp	3	0.3	10610	17191	88747	3700	1710	3	1621	9	241	529	36
38-3-19	2	sp	7	<LOD	16315	39822	106706	8052	6748	2	3590	36	1779	685	36
41-2-3	2	sp-core	<LOD	<LOD	<LOD	266773	<LOD	<LOD	<LOD	2	753	597	167979	1126	263
41-2-4	2	sp-rim	<LOD	<LOD	<LOD	238977	<LOD	<LOD	<LOD	4	764	523	145233	1000	206
41-3-11	1	sp-rim	<LOD	<LOD	<LOD	215663	<LOD	<LOD	<LOD	3	1948	595	171978	1449	204
41-3-5	2	sp-core	<LOD	<LOD	<LOD	196273	<LOD	<LOD	<LOD	<LOD	10918	869	161928	1759	216
41-3-6	2	sp-rim	5	<LOD	4906	155769	32269	777	7607	7	32181	1456	151497	1899	212

Sample	Type	Spot	Ni60_ppm	Cu65_ppm	Zn66_ppm	Ga71_ppm	Rb85_ppm	Sr88_ppm	Y89_ppm	Zr90_ppm	Nb93_ppm	Cs133_ppm	Ba137_ppm	La139_ppm
14-1-5	2	sp-core	2443	7	1843	145	<LOD	<LOD	<LOD	1	0.3	<LOD	<LOD	
14-1-6	2	sp-rim	2794	9	1623	149	<LOD	<LOD	0	5	2.8	<LOD	2.3	0.36
14-2-11	2	sp	3140	<LOD	2226	149	<LOD	<LOD	<LOD	8	8.6	<LOD	59.1	0.31
14-3-1	2	sp	2370	14	1498	91	<LOD	<LOD	<LOD	6	2.3	<LOD	<LOD	0.07
14-3-2	2	sp	2818	11	1777	131	<LOD	<LOD	0	9	4.3	<LOD	5.3	0.75
18-1-11	2	sp	2432	18	1069	80	1	3	0	76	80.0	<LOD	2.3	0.22
18-2-14	2	sp	2742	62	1300	104	23	56	0	69	88.3	<LOD	65.3	1.33
30-3-11	1	sp-rim	2540	18	1603	107	<LOD	0	0	21	12.3	<LOD	0.4	0.02
30-3-12	1	sp-core	2326	74	1330	111	2	31	1	66	27.2	<LOD	19.6	3.01
30-3-13	1	sp-core	2232	67	1531	109	<LOD	86	1	4	3.1	<LOD	41.1	7.78
38-2-12	2	sp	730	4	44	2	4	76	3	63	34.4	<LOD	213.6	9.07
38-3-19	2	sp	399	40	65	9	11	273	4	86	50.5	<LOD	312.1	12.57
41-2-3	2	sp-core	2818	<LOD	1269	90	<LOD	<LOD	<LOD	0	0.2	<LOD	<LOD	
41-2-4	2	sp-rim	2255	<LOD	940	77	<LOD	<LOD	<LOD	0	0.2	<LOD	<LOD	
41-3-11	1	sp-rim	1993	<LOD	1196	87	<LOD	<LOD	<LOD	1	0.3	<LOD	<LOD	
41-3-5	2	sp-core	2140	<LOD	2104	98	<LOD	0	<LOD	2	1.1	<LOD	<LOD	
41-3-6	2	sp-rim	2801	21	2017	115	<LOD	129	0	9	6.0	<LOD	93.5	3.79

Sample	Type	Spot	Ce140_ppm	Pr141_ppm	Nd146_ppm	Sm147_ppm	Eu153_ppm	Gd157_ppm	Tb159_ppm	Dy163_ppm	Ho165_ppm	Er166_ppm	Tm169_ppm
14-1-5	2.00	sp-core		<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14-1-6	2.00	sp-rim	0.83	0.11	0.14	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14-2-11	2.00	sp	0.45	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14-3-1	2.00	sp	0.08	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14-3-2	2.00	sp	1.61	0.12	0.78	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-1-11	2.00	sp	0.50	0.03	0.06	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-14	2.00	sp	2.78	0.28	0.75	0.21	0.06	<LOD	0.03	0.11	0.02	<LOD	<LOD
30-3-11	1.00	sp-rim	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-12	1.00	sp-core	5.77	0.60	2.17	0.35	0.08	0.15	0.03	0.47	0.01	0.16	<LOD
30-3-13	1.00	sp-core	13.27	1.23	3.77	0.70	0.09	0.73	0.02	0.12	0.06	0.07	<LOD
38-2-12	2.00	sp	15.06	1.60	5.62	0.70	0.37	0.66	0.07	0.61	0.09	0.30	0.04
38-3-19	2.00	sp	21.92	2.12	6.59	0.86	0.29	1.02	0.05	0.58	0.10	0.36	<LOD
41-2-3	2.00	sp-core		<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-2-4	2.00	sp-rim		<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-3-11	1.00	sp-rim		<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-3-5	2.00	sp-core	0.09	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-3-6	2.00	sp-rim	6.35	0.45	1.33	<LOD	0.16	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Sample	Type	Spot	Yb173_ppm	Lu175_ppm	Hf178_ppm	Ta181_ppm	Pb208_ppm	Th232_ppm	U238_ppm
14-1-5	2.00	sp-core	<LOD	<LOD	0.08	<LOD	<LOD	<LOD	<LOD
14-1-6	2.00	sp-rim	<LOD	<LOD	0.10	0.16	<LOD	0.03	<LOD
14-2-11	2.00	sp	<LOD	<LOD	0.31	0.57	<LOD	0.06	<LOD
14-3-1	2.00	sp	<LOD	<LOD	0.03	0.16	0.27	0.01	0.01
14-3-2	2.00	sp	<LOD	<LOD	0.28	0.33	0.32	0.10	0.02
18-1-11	2.00	sp	<LOD	<LOD	1.60	6.00	<LOD	0.03	0.06
18-2-14	2.00	sp	<LOD	<LOD	2.09	5.42	6.52	0.52	0.34
30-3-11	1.00	sp-rim	<LOD	<LOD	0.71	1.02	<LOD	<LOD	<LOD
30-3-12	1.00	sp-core	<LOD	<LOD	1.63	2.24	1.63	2.07	0.74
30-3-13	1.00	sp-core	<LOD	<LOD	<LOD	0.04	0.64	1.21	0.36
38-2-12	2.00	sp	0.27	0.04	1.27	1.68	1.29	1.78	0.80
38-3-19	2.00	sp	0.17	0.04	0.98	2.97	3.46	3.99	1.18
41-2-3	2.00	sp-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-2-4	2.00	sp-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-3-11	1.00	sp-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-3-5	2.00	sp-core	<LOD	<LOD	<LOD	0.05	<LOD	<LOD	<LOD
41-3-6	2.00	sp-rim	<LOD	<LOD	0.20	0.40	1.43	0.08	0.06

Sample	Type	Spot	Li7_ppm	Be9_ppm	Na23_ppm	Mg24_ppm	Al27_ppm	K39_ppm	Ca42_ppm	Sc45_ppm
14-1-1	1	ol-core	7	<LOD	51	244193	57	<LOD	379	7
14-1-7	1	ol-rim	8	<LOD	70	242216	78	<LOD	768	6
14-2-3	1	trav: ol-core	5	<LOD	182	242946	535	45	1060	5
14-2-7	1	trav: ol-rim	8	<LOD	202	246604	153	<LOD	435	5
14-3-5	1	ol-core	8	<LOD	74	247547	78	<LOD	670	6
14-3-6	1	ol-rim	7	<LOD	69	243518	222	11	1437	6
18-1-14	1	ol-rim	5	<LOD	81	216766	135	<LOD	1819	5
18-1-15	1	ol-core	6	<LOD	<LOD	221664	88	<LOD	1070	4
18-1-8	1	ol-rim	4	<LOD	67	220850	237	24	2262	4
18-1-9	1	ol-core	6	<LOD	<LOD	228754	79	<LOD	705	5
18-2-10	1	ol-rim	6	<LOD	82	231281	138	<LOD	1355	5
18-2-19	1	ol-rim	5	<LOD	65	242163	149	<LOD	1473	5
18-2-20	1	ol-core	7	<LOD	99	233113	85	<LOD	1167	7
18-2-7	2	ol-rim	4	<LOD	94	228719	212	<LOD	1203	11
18-2-9	1	ol-core	8	<LOD	66	234921	54	<LOD	737	5
30-1-1	1	trav: ol-rim	7	<LOD	128	236129	806	70	1462	7
30-1-11	2	ol-core	10	<LOD	101	247317	121	<LOD	1248	6
30-1-12	2	ol-rim	11	<LOD	780	241023	481	81	1822	5
30-1-6	1	trav: ol-core	6	<LOD	73	260398	92	<LOD	509	4
30-3-10	1	ol-rim	7	<LOD	269	226374	2206	573	1511	4
30-3-5	2	ol-core	8	<LOD	111	236508	112	<LOD	1004	4
30-3-6	2	ol-rim	6	<LOD	72	231478	202	9	1497	6
30-3-9	1	ol-core	7	<LOD	70	252469	40	<LOD	638	5
38-1-1	1	ol-core	7	<LOD	53	254319	60	<LOD	302	6
38-1-13	2	ol-core	4	<LOD	72	242626	506	<LOD	3374	5
38-1-2	1	ol-rim	7	<LOD	92	242914	792	42	1016	5
38-1-7	2	ol-core	5	<LOD	129	232565	716	87	2178	4
38-2-1	2	ol-core	7	<LOD	93	259185	59	21	377	4
38-2-10	2	ol-core	8	<LOD	74	256242	76	<LOD	298	6
38-2-11	2	ol-rim	7	<LOD	138	252806	549	65	956	5
38-2-2	2	ol-rim	7	<LOD	121	265540	125	<LOD	913	5
38-2-3	1	ol-core	8	<LOD	423	244054	2999	678	586	4
38-2-5	1	ol-core	7	<LOD	51	267724	55	<LOD	287	4
38-3-20	1	ol-core	7	<LOD	62	253948	58	<LOD	287	6
38-3-21	1	ol-rim	7	<LOD	100	239147	198	86	643	5
38-4-10	2	ol-rim	6	<LOD	14511	204319	19851	2946	2481	5
38-4-14	1	ol-core	7	<LOD	39	263959	57	<LOD	362	4
38-4-15	1	ol-rim	5	<LOD	62	255214	274	19	1378	5
38-4-19	2	ol-core	5	<LOD	1919	251287	12743	355	2292	4
38-4-23	1	ol-core	6	<LOD	52	257866	55	<LOD	312	5
38-5-10	1	ol-core	6	<LOD	183	250886	836	131	803	5
38-5-7	1	ol-rim	9	<LOD	128	248562	1514	214	1004	4
38-5-8	1	ol-core	8	<LOD	117	250611	62	20	221	4
38-6-5	1	ol-rim	7	<LOD	70	255771	62	<LOD	802	30
38-6-6	1	ol-core	11	0.4	340	229072	12437	524	395	6
41-2-10	1	ol-core	6	<LOD	61	260333	72	<LOD	394	4
41-2-11	1	ol-rim	5	<LOD	87	265849	2280	25	956	4
41-3-8	1	ol-rim	9	<LOD	104	263436	125	<LOD	928	4
41-3-9	1	ol-core	7	<LOD	70	272369	75	<LOD	294	5
41-4-3	1	ol-core	8	<LOD	78	275730	52	<LOD	833	5
41-4-4	1	ol-rim	6	<LOD	48	274947	63	<LOD	391	4

Sample	Type	Spot	Ti47_ppm	V51_ppm	Cr53_ppm	Mn55_ppm	Co59_ppm	Ni60_ppm	Cu65_ppm	Zn66_ppm
14-1-1	1	ol-core	223	6	183	2073	142	1901	<LOD	164
14-1-7	1	ol-rim	4014	77	4292	2090	145	1807	11	199
14-2-3	1	trav: ol-core	390	6	92	1612	121	2171	3	106
14-2-7	1	trav: ol-rim	1692	11	68	1354	100	1759	9	93
14-3-5	1	ol-core	18	5	151	1640	155	3133	<LOD	157
14-3-6	1	ol-rim	613	23	574	1772	144	2373	4	146
18-1-14	1	ol-rim	43	3	87	1489	134	2639	1	146
18-1-15	1	ol-core	53	3	49	1543	136	2621	<LOD	154
18-1-8	1	ol-rim	70	3	79	1544	135	2666	1	151
18-1-9	1	ol-core	149	5	168	1511	133	2699	2	148
18-2-10	1	ol-rim	83	3	97	1613	128	2480	2	147
18-2-19	1	ol-rim	54	3	95	1624	132	2583	2	150
18-2-20	1	ol-core	13	7	182	1001	133	2937	<LOD	89
18-2-7	2	ol-rim	94	17	1458	1142	132	2706	2	108
18-2-9	1	ol-core	15	3	94	1146	147	3108	2	78
30-1-1	1	trav: ol-rim	30	8	296	1331	133	2838	<LOD	99
30-1-11	2	ol-core	15	8	153	1121	145	3095	<LOD	88
30-1-12	2	ol-rim	144	5	59	1885	182	1671	3	214
30-1-6	1	trav: ol-core	78	3	18	1749	186	1651	<LOD	205
30-3-10	1	ol-rim	112	4	242	1762	173	1673	3	219
30-3-5	2	ol-core	62	4	46	1705	181	1695	<LOD	200
30-3-6	2	ol-rim	121	7	86	1933	190	1795	<LOD	220
30-3-9	1	ol-core	72	4	62	1965	191	1752	<LOD	206
38-1-1	1	ol-core	132	6	110	1595	179	1755	<LOD	206
38-1-13	2	ol-core	1433	10	48	1718	156	1422	6	190
38-1-2	1	ol-rim	133	5	63	1849	181	1723	<LOD	218
38-1-7	2	ol-core	84	3	36	1847	185	1629	<LOD	214
38-2-1	2	ol-core	5	3	33	1181	145	2854	1	108
38-2-10	2	ol-core	15	4	173	1593	146	2907	<LOD	164
38-2-11	2	ol-rim	99	5	118	1767	146	2418	2	158
38-2-2	2	ol-rim	117	5	112	1655	142	2483	7	155
38-2-3	1	ol-core	6	3	60	1196	148	2953	1	139
38-2-5	1	ol-core	32	2	68	1406	140	2724	1	140
38-3-20	1	ol-core	199	6	130	1986	140	1925	3	162
38-3-21	1	ol-rim	79	4	111	1468	133	2690	1	128
38-4-10	2	ol-rim	36	3	84	1460	135	2777	<LOD	125
38-4-14	1	ol-core	34	3	81	1457	137	2808	1	130
38-4-15	1	ol-rim	39	4	86	1533	135	2788	1	135
38-4-19	2	ol-core	38	2	59	1587	142	2820	<LOD	147
38-4-23	1	ol-core	1952	14	73	1278	103	1982	8	102
38-5-10	1	ol-core	58	2	77	1522	137	2605	4	150
38-5-7	1	ol-rim	35	2	64	1548	134	2638	<LOD	129
38-5-8	1	ol-core	34	3	59	1556	135	2614	<LOD	134
38-6-5	1	ol-rim	6334	100	2253	1105	71	1293	4	66
38-6-6	1	ol-core	2406	102	10016	1749	138	2455	6	199
41-2-10	1	ol-core	41	3	62	1536	139	2727	<LOD	115
41-2-11	1	ol-rim	67	4	139	1539	132	2569	9	108
41-3-8	1	ol-rim	530	6	136	1533	124	2240	10	102
41-3-9	1	ol-core	171	6	393	1418	134	2686	<LOD	102
41-4-3	1	ol-core	36	2	68	1631	134	2661	1	137
41-4-4	1	ol-rim	124	2	50	1454	130	2652	24	136

Sample	Type	Spot	Ga71_ppm	Rb85_ppm	Sr88_ppm	Y89_ppm	Zr90_ppm	Nb93_ppm	Cs133_ppm	Ba137_ppm
14-1-1	1	ol-core	0	<LOD	1	1	1	0.1	<LOD	<LOD
14-1-7	1	ol-rim	5	5	11	1	16	10.8	<LOD	17.2
14-2-3	1	trav: ol-core	1	1	5	1	5	5.0	<LOD	6.6
14-2-7	1	trav: ol-rim	4	8	48	2	47	32.2	0.2	81.1
14-3-5	1	ol-core	<LOD	<LOD	<LOD	0	0	<LOD	<LOD	<LOD
14-3-6	1	ol-rim	1	<LOD	0	0	1	1.0	<LOD	<LOD
18-1-14	1	ol-rim	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
18-1-15	1	ol-core	<LOD	<LOD	0	0	0	0.0	<LOD	<LOD
18-1-8	1	ol-rim	0	<LOD	1	0	1	0.3	<LOD	0.9
18-1-9	1	ol-core	0	<LOD	2	0	1	0.9	<LOD	5.8
18-2-10	1	ol-rim	0	<LOD	1	0	0	0.2	<LOD	3.4
18-2-19	1	ol-rim	<LOD	<LOD	0	0	0	<LOD	<LOD	0.1
18-2-20	1	ol-core	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
18-2-7	2	ol-rim	1	<LOD	0	1	1	1.4	<LOD	0.4
18-2-9	1	ol-core	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
30-1-1	1	trav: ol-rim	<LOD	<LOD	<LOD	0	0	<LOD	<LOD	<LOD
30-1-11	2	ol-core	0	<LOD	0	0	0	<LOD	<LOD	<LOD
30-1-12	2	ol-rim	0	<LOD	1	1	0	0.1	<LOD	0.3
30-1-6	1	trav: ol-core	<LOD	<LOD	<LOD	0	<LOD	0.0	<LOD	<LOD
30-3-10	1	ol-rim	<LOD	<LOD	0	0	0	<LOD	<LOD	0.1
30-3-5	2	ol-core	0	<LOD	<LOD	0	0	<LOD	<LOD	<LOD
30-3-6	2	ol-rim	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
30-3-9	1	ol-core	0	<LOD	0	0	0	0.0	<LOD	<LOD
38-1-1	1	ol-core	0	<LOD	<LOD	0	0	<LOD	<LOD	<LOD
38-1-13	2	ol-core	4	10	17	2	44	24.7	0.1	10.3
38-1-2	1	ol-rim	0	<LOD	0	0	0	<LOD	<LOD	<LOD
38-1-7	2	ol-core	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
38-2-1	2	ol-core	<LOD	<LOD	1	0	0	0.1	<LOD	0.1
38-2-10	2	ol-core	0	<LOD	<LOD	0	0	<LOD	<LOD	0.3
38-2-11	2	ol-rim	0	<LOD	1	1	1	0.3	<LOD	0.4
38-2-2	2	ol-rim	1	2	2	1	0	0.5	<LOD	<LOD
38-2-3	1	ol-core	<LOD	<LOD	0	0	<LOD	<LOD	<LOD	<LOD
38-2-5	1	ol-core	<LOD	<LOD	<LOD	0	0	<LOD	<LOD	<LOD
38-3-20	1	ol-core	1	<LOD	2	1	1	0.4	<LOD	<LOD
38-3-21	1	ol-rim	0	<LOD	2	0	1	0.4	<LOD	1.9
38-4-10	2	ol-rim	<LOD	<LOD	0	0	0	0.1	<LOD	0.3
38-4-14	1	ol-core	<LOD	<LOD	0	0	0	0.1	<LOD	<LOD
38-4-15	1	ol-rim	0	<LOD	0	0	0	0.0	<LOD	0.6
38-4-19	2	ol-core	0	<LOD	0	0	0	0.0	<LOD	<LOD
38-4-23	1	ol-core	4	8	40	3	59	30.7	0.2	59.3
38-5-10	1	ol-core	0	<LOD	2	0	1	0.4	<LOD	0.5
38-5-7	1	ol-rim	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
38-5-8	1	ol-core	<LOD	<LOD	<LOD	0	0	<LOD	<LOD	<LOD
38-6-5	1	ol-rim	6	3	61	11	91	9.7	0.1	18.0
38-6-6	1	ol-core	10	1	11	1	9	5.2	<LOD	5.8
41-2-10	1	ol-core	0	<LOD	0	0	0	0.0	<LOD	0.4
41-2-11	1	ol-rim	1	1	2	0	2	1.2	0.1	2.1
41-3-8	1	ol-rim	1	4	14	1	14	11.0	<LOD	40.3
41-3-9	1	ol-core	1	<LOD	2	0	1	0.4	0.1	3.5
41-4-3	1	ol-core	<LOD	<LOD	0	0	0	<LOD	<LOD	<LOD
41-4-4	1	ol-rim	2	2	3	0	9	3.3	<LOD	0.2

Sample	Type	Spot	La139_ppm	Ce140_ppm	Pr141_ppm	Nd146_ppm	Sm147_ppm	Eu153_ppm	Gd157_ppm
14-1-1	1	ol-core	0.10	0.19	0.05	0.33	0.09	<LOD	0.14
14-1-7	1	ol-rim	2.05	4.04	0.32	0.93	0.34	<LOD	0.12
14-2-3	1	trav: ol-core	0.97	1.96	0.13	0.64	<LOD	<LOD	<LOD
14-2-7	1	trav: ol-rim	6.32	11.54	1.14	3.75	0.69	0.30	0.48
14-3-5	1	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14-3-6	1	ol-rim	0.10	0.08	0.02	0.05	<LOD	<LOD	<LOD
18-1-14	1	ol-rim	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	<LOD
18-1-15	1	ol-core	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	0.03
18-1-8	1	ol-rim	0.12	0.28	0.01	0.05	<LOD	<LOD	<LOD
18-1-9	1	ol-core	0.19	0.44	0.07	0.28	<LOD	0.01	0.03
18-2-10	1	ol-rim	0.05	0.10	0.01	0.04	<LOD	<LOD	0.04
18-2-19	1	ol-rim	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	0.02
18-2-20	1	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-7	2	ol-rim	0.07	0.16	0.02	0.03	<LOD	<LOD	<LOD
18-2-9	1	ol-core	<LOD	<LOD	<LOD	0.01	<LOD	<LOD	<LOD
30-1-1	1	trav: ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-11	2	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-12	2	ol-rim	<LOD	0.02	0.01	<LOD	<LOD	<LOD	<LOD
30-1-6	1	trav: ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-10	1	ol-rim	0.03	0.03	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-5	2	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.07
30-3-6	2	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-9	1	ol-core	0.01	0.03	<LOD	<LOD	<LOD	<LOD	<LOD
38-1-1	1	ol-core	<LOD	0.02	<LOD	<LOD	<LOD	<LOD	<LOD
38-1-13	2	ol-core	7.13	12.70	1.07	3.32	0.62	0.18	0.46
38-1-2	1	ol-rim	<LOD	0.01	<LOD	0.03	<LOD	0.01	<LOD
38-1-7	2	ol-core	<LOD	<LOD	<LOD	0.03	<LOD	<LOD	<LOD
38-2-1	2	ol-core	0.04	0.08	0.01	<LOD	<LOD	<LOD	<LOD
38-2-10	2	ol-core	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-11	2	ol-rim	0.02	0.01	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-2	2	ol-rim	0.02	0.03	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-3	1	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-5	1	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
38-3-20	1	ol-core	0.03	0.05	<LOD	0.03	<LOD	<LOD	0.06
38-3-21	1	ol-rim	0.10	0.22	0.02	<LOD	<LOD	<LOD	0.04
38-4-10	2	ol-rim	0.01	0.01	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-14	1	ol-core	0.01	0.02	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-15	1	ol-rim	0.03	0.11	0.01	0.05	0.06	<LOD	<LOD
38-4-19	2	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-23	1	ol-core	8.94	17.25	1.72	5.84	1.05	0.48	0.97
38-5-10	1	ol-core	0.03	0.05	<LOD	<LOD	<LOD	<LOD	<LOD
38-5-7	1	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
38-5-8	1	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
38-6-5	1	ol-rim	5.97	18.23	2.86	14.78	3.83	1.20	3.60
38-6-6	1	ol-core	2.21	3.60	0.30	0.89	0.10	0.06	0.10
41-2-10	1	ol-core	0.02	0.04	0.00	0.04	<LOD	<LOD	<LOD
41-2-11	1	ol-rim	0.12	0.29	0.02	0.10	<LOD	<LOD	<LOD
41-3-8	1	ol-rim	3.56	5.57	0.52	1.21	0.28	0.14	0.12
41-3-9	1	ol-core	0.14	0.49	0.04	<LOD	<LOD	<LOD	0.05
41-4-3	1	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-4-4	1	ol-rim	0.03	0.04	0.00	<LOD	<LOD	<LOD	<LOD

Sample	Type	Spot	Tb159_ppm	Dy163_ppm	Ho165_ppm	Er166_ppm	Tm169_ppm	Yb173_ppm	Lu175_ppm
14-1-1	1.00	ol-core	0.02	0.15	0.03	0.20	0.03	0.24	0.04
14-1-7	1.00	ol-rim	0.02	0.16	0.05	0.13	0.03	<LOD	0.06
14-2-3	1.00	trav: ol-core	0.01	0.09	<LOD	0.11	0.05	<LOD	0.02
14-2-7	1.00	trav: ol-rim	0.08	0.38	0.08	0.18	<LOD	0.17	0.02
14-3-5	1.00	ol-core	<LOD	<LOD	<LOD	0.07	<LOD	<LOD	<LOD
14-3-6	1.00	ol-rim	<LOD	<LOD	0.02	0.06	<LOD	0.09	0.03
18-1-14	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD	0.02	<LOD
18-1-15	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01
18-1-8	1.00	ol-rim	0.00	<LOD	<LOD	0.02	<LOD	<LOD	0.01
18-1-9	1.00	ol-core	0.00	0.03	0.01	0.05	<LOD	0.10	0.02
18-2-10	1.00	ol-rim	<LOD	0.03	0.01	0.05	0.01	0.03	<LOD
18-2-19	1.00	ol-rim	0.00	<LOD	<LOD	0.03	<LOD	<LOD	<LOD
18-2-20	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-7	2.00	ol-rim	<LOD	0.06	0.01	0.07	0.02	0.05	0.02
18-2-9	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-1	1.00	trav: ol-rim	<LOD	<LOD	0.01	0.03	0.00	0.02	0.00
30-1-11	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-12	2.00	ol-rim	<LOD	0.08	0.02	0.10	0.03	0.16	0.05
30-1-6	1.00	trav: ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-10	1.00	ol-rim	0.01	<LOD	0.02	0.09	<LOD	0.08	0.02
30-3-5	2.00	ol-core	<LOD	<LOD	0.01	<LOD	0.01	<LOD	<LOD
30-3-6	2.00	ol-rim	<LOD	0.02	0.01	0.04	<LOD	<LOD	0.01
30-3-9	1.00	ol-core	<LOD	<LOD	0.01	0.02	<LOD	0.02	0.01
38-1-1	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01
38-1-13	2.00	ol-core	0.06	0.41	0.10	0.23	0.04	0.29	0.06
38-1-2	1.00	ol-rim	<LOD	<LOD	0.01	0.05	0.01	<LOD	0.01
38-1-7	2.00	ol-core	<LOD	<LOD	<LOD	0.02	<LOD	<LOD	<LOD
38-2-1	2.00	ol-core	<LOD	0.04	<LOD	0.03	<LOD	<LOD	<LOD
38-2-10	2.00	ol-core	<LOD	0.03	<LOD	0.07	<LOD	0.08	0.02
38-2-11	2.00	ol-rim	<LOD	0.05	0.01	0.07	0.02	0.15	0.02
38-2-2	2.00	ol-rim	0.01	0.04	0.03	0.12	0.02	0.22	0.02
38-2-3	1.00	ol-core	<LOD	<LOD	<LOD	0.01	0.01	<LOD	0.01
38-2-5	1.00	ol-core	<LOD	<LOD	<LOD	0.01	<LOD	<LOD	<LOD
38-3-20	1.00	ol-core	0.01	0.12	0.02	0.10	0.04	0.18	0.04
38-3-21	1.00	ol-rim	<LOD	0.04	0.01	0.05	<LOD	0.06	0.01
38-4-10	2.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01
38-4-14	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01
38-4-15	1.00	ol-rim	<LOD	0.04	0.01	0.04	<LOD	<LOD	0.02
38-4-19	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-23	1.00	ol-core	0.11	0.67	0.14	0.32	0.04	0.39	0.03
38-5-10	1.00	ol-core	<LOD	<LOD	0.01	<LOD	<LOD	0.05	0.01
38-5-7	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
38-5-8	1.00	ol-core	<LOD	<LOD	<LOD	0.01	<LOD	<LOD	<LOD
38-6-5	1.00	ol-rim	0.49	2.61	0.42	1.04	0.12	0.58	0.09
38-6-6	1.00	ol-core	0.02	0.16	0.05	0.10	0.02	0.22	0.04
41-2-10	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00
41-2-11	1.00	ol-rim	<LOD	<LOD	<LOD	0.02	<LOD	<LOD	<LOD
41-3-8	1.00	ol-rim	0.01	0.13	0.02	0.09	0.02	0.08	0.02
41-3-9	1.00	ol-core	<LOD	0.05	0.01	0.02	0.01	<LOD	<LOD
41-4-3	1.00	ol-core	<LOD	<LOD	0.01	<LOD	0.00	<LOD	0.01
41-4-4	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	0.01	<LOD	<LOD

Sample	Type	Spot	Hf178_ppm	Ta181_ppm	Pb208_ppm	Th232_ppm	U238_ppm
14-1-1	1.00	ol-core	0.09	<LOD	<LOD	<LOD	<LOD
14-1-7	1.00	ol-rim	0.26	0.53	0.88	0.45	0.27
14-2-3	1.00	trav: ol-core	0.10	0.17	0.39	0.12	0.08
14-2-7	1.00	trav: ol-rim	0.77	1.37	1.17	1.32	0.56
14-3-5	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
14-3-6	1.00	ol-rim	<LOD	0.07	<LOD	<LOD	<LOD
18-1-14	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
18-1-15	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
18-1-8	1.00	ol-rim	<LOD	0.01	<LOD	<LOD	0.01
18-1-9	1.00	ol-core	0.02	0.02	0.06	0.03	0.02
18-2-10	1.00	ol-rim	<LOD	0.01	0.27	0.00	<LOD
18-2-19	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-20	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-7	2.00	ol-rim	<LOD	0.04	0.37	0.01	<LOD
18-2-9	1.00	ol-core	<LOD	<LOD	0.06	<LOD	<LOD
30-1-1	1.00	trav: ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-11	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-12	2.00	ol-rim	<LOD	<LOD	0.26	<LOD	<LOD
30-1-6	1.00	trav: ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-10	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-5	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-6	2.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-9	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-1-1	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-1-13	2.00	ol-core	0.61	1.23	0.80	2.03	0.86
38-1-2	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
38-1-7	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-1	2.00	ol-core	<LOD	<LOD	<LOD	0.01	0.01
38-2-10	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-11	2.00	ol-rim	<LOD	0.01	<LOD	<LOD	<LOD
38-2-2	2.00	ol-rim	<LOD	0.01	<LOD	<LOD	0.01
38-2-3	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-2-5	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-3-20	1.00	ol-core	0.03	0.01	0.09	<LOD	0.01
38-3-21	1.00	ol-rim	<LOD	0.03	0.16	0.01	0.01
38-4-10	2.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-14	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-15	1.00	ol-rim	<LOD	0.00	<LOD	<LOD	<LOD
38-4-19	2.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-4-23	1.00	ol-core	0.93	1.82	0.80	1.75	0.64
38-5-10	1.00	ol-core	0.03	0.03	0.49	<LOD	<LOD
38-5-7	1.00	ol-rim	<LOD	<LOD	<LOD	<LOD	<LOD
38-5-8	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
38-6-5	1.00	ol-rim	3.01	0.78	0.28	0.59	0.17
38-6-6	1.00	ol-core	0.17	0.29	0.19	0.30	0.12
41-2-10	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
41-2-11	1.00	ol-rim	0.05	0.04	0.19	<LOD	<LOD
41-3-8	1.00	ol-rim	0.18	0.39	0.86	0.53	0.15
41-3-9	1.00	ol-core	<LOD	0.02	<LOD	0.01	0.01
41-4-3	1.00	ol-core	<LOD	<LOD	<LOD	<LOD	<LOD
41-4-4	1.00	ol-rim	0.22	0.28	<LOD	0.01	0.01

Sample	Type	Spot	Li7_μpm	Be9_μpm	Na23_μpm	Mg24_μpm	Al27_μpm	K39_μpm	Ca42_μpm	Sc45_μpm	Ti47_μpm	V51_μpm	Cr53_μpm
30-1-20	1	opx-core	2	<LOD	585	176596	11183	14	5808	13	183	53	2710
30-1-21	1	opx-rim	2	<LOD	860	167145	13785	24	13396	16	763	66	2920
38-6-3	1	opx-rim	4	<LOD	1029	178606	8585	351	16412	11	731	36	1529
38-6-4	1	opx-core	2	<LOD	661	185499	8216	17	5077	10	724	35	1477
41-2-1	1	opx-core	3	0.2	547	179335	23314	<LOD	4602	19	413	83	3570
41-2-2	1	opx-rim	3	<LOD	565	176639	22807	<LOD	4834	19	380	78	3685
41-4-1	1	opx-core	2	<LOD	509	185231	21733	<LOD	4812	19	413	78	3738
41-4-2	1	opx-rim	2	<LOD	645	181367	25438	20	5407	20	506	99	4038

Sample	Type	Spot	Mn55_μpm	Co59_μpm	Ni60_μpm	Cu65_μpm	Zn66_μpm	Ga71_μpm	Rb85_μpm	Sr88_μpm	Y89_μpm	Zr90_μpm	Nb93_μpm
30-1-20	1	opx-core	1173	57	665	<LOD	55	3	<LOD	2	1	1	0.1
30-1-21	1	opx-rim	1168	58	633	<LOD	63	4	<LOD	10	2	4	0.2
38-6-3	1	opx-rim	1589	63	861	6	95	5	1	13	2	16	1.2
38-6-4	1	opx-core	1653	58	719	2	92	5	<LOD	1	1	6	0.3
41-2-1	1	opx-core	1153	59	773	1	46	4	<LOD	0	1	7	0.0
41-2-2	1	opx-rim	1152	59	758	<LOD	48	4	<LOD	1	1	7	0.0
41-4-1	1	opx-core	1188	58	757	<LOD	51	5	<LOD	0	1	7	0.1
41-4-2	1	opx-rim	1163	58	759	<LOD	51	4	<LOD	1	1	8	0.5

Sample	Type	Spot	Cs133_μpm	Ba137_μpm	La139_μpm	Ce140_μpm	Pr141_μpm	Nd146_μpm	Sm147_μpm	Eu153_μpm	Gd157_μpm	Tb159_μpm	Dy163_μpm
30-1-20	1	opx-core	<LOD	0.3	0.10	0.30	0.04	0.22	0.13	0.03	0.11	0.02	0.15
30-1-21	1	opx-rim	<LOD	0.5	0.72	2.31	0.42	1.87	0.53	0.18	0.55	0.06	0.40
38-6-3	1	opx-rim	<LOD	0.6	0.69	2.27	0.40	1.70	0.40	0.26	0.55	0.06	0.40
38-6-4	1	opx-core	<LOD	0.1	<LOD	0.05	0.02	0.14	<LOD	0.04	0.05	0.03	0.20
41-2-1	1	opx-core	<LOD	<LOD	0.02	0.09	0.02	0.08	<LOD	0.04	0.07	0.03	0.15
41-2-2	1	opx-rim	<LOD	<LOD	0.04	0.15	<LOD	0.17	<LOD	0.03	0.07	0.01	0.14
41-4-1	1	opx-core	<LOD	<LOD	0.01	0.09	0.03	0.07	0.06	<LOD	0.12	0.02	0.11
41-4-2	1	opx-rim	<LOD	<LOD	0.10	0.31	0.06	0.22	0.07	0.02	0.14	0.01	0.14

Sample	Type	Spot	Ho165_μpm	Er166_μpm	Tm169_μpm	Yb173_μpm	Lu175_μpm	Hf178_μpm	Ta181_μpm	Pb208_μpm	Th232_μpm	U238_μpm
30-1-20	1	opx-core	0.02	0.11	0.02	0.18	0.02	<LOD	<LOD	<LOD	0.01	0.01
30-1-21	1	opx-rim	0.10	0.25	0.03	0.25	0.05	0.11	0.01	0.10	0.05	0.01
38-6-3	1	opx-rim	0.09	0.28	0.04	0.29	0.05	0.36	0.05	0.29	0.06	0.02
38-6-4	1	opx-core	0.04	0.15	<LOD	0.15	0.04	0.12	<LOD	<LOD	<LOD	<LOD
41-2-1	1	opx-core	0.04	0.16	0.01	0.18	0.04	0.09	<LOD	<LOD	<LOD	<LOD
41-2-2	1	opx-rim	0.03	0.11	0.03	0.15	0.05	0.12	<LOD	<LOD	0.01	0.01
41-4-1	1	opx-core	0.04	0.12	0.03	0.16	0.04	0.12	<LOD	<LOD	<LOD	<LOD
41-4-2	1	opx-rim	0.04	0.17	0.03	0.22	0.05	0.15	<LOD	<LOD	0.04	0.01

Sample	Type	Spot	Li7_ppm	Be9_ppm	Na23_ppm	Mg24_ppm	Al27_ppm	K39_ppm	Ca42_ppm	Sc45_ppm	Ti47_ppm
14-1-2	2	cpx-core	24	0.1	10490	82606	29450	16	149350	56	6295
14-1-3	2	cpx-rim	3	2.0	11023	69836	48843	844	158815	65	23134
14-2-8	2	cpx-core	30	0.4	10551	79365	34297	78	145045	61	7884
14-2-9	2	cpx-rim	3	0.5	4412	73881	33467	123	155010	69	16574
14-3-3	2	cpx-core	4	<LOD	12683	81043	21255	1063	144591	41	4745
14-3-4	2	cpx-rim	3	<LOD	8072	84519	33286	1347	160139	62	10761
18-1-12	2	cpx-core	<LOD	<LOD	4960	75812	36905	454	178553	66	16223
18-1-13	2	cpx-rim	<LOD	0.8	3836	68410	28775	285	150187	75	11056
18-1-7	2	cpx-rim	4	<LOD	4670	53948	45503	112	146835	37	20125
18-2-11	2	cpx-core	2	1.3	6824	66128	38743	199	164988	62	22912
18-2-12	2	cpx-rim	2	<LOD	7024	71656	36470	29	155975	61	20752
18-2-15	1	cpx-core	12	0.4	8655	86355	14634	<LOD	152027	41	3437
18-2-16	1	cpx-rim	4	<LOD	7787	84242	16870	11	142698	42	3879
18-2-17	1	cpx-core	4	0.7	10982	83659	24520	<LOD	157984	47	6368
18-2-18	1	cpx-rim	3	<LOD	4013	76802	22874	34	150221	51	7549
18-2-5	2	cpx-core	6	1.1	3950	53092	53039	84	170555	54	27984
30-1-13	2	cpx-core	4	<LOD	8835	92770	28137	3246	146497	74	2035
30-1-14	2	cpx-rim	6	0.3	6741	99068	21688	1427	127002	36	3503
30-1-15	2	cpx-core	7	0.8	5658	110423	21608	1106	130549	39	4523
30-1-16	2	cpx-rim	2	1.6	5578	75633	31126	159	163897	78	16987
30-3-7	2	cpx-core	5	0.3	8465	98772	22971	3354	135565	54	3758
30-3-8	2	cpx-rim	3	0.6	9163	71837	29070	2511	133959	45	8951
38-1-11	2	cpx-core	5	2.3	10666	72776	65435	4148	181000	59	30466
38-1-12	2	cpx-rim	3	1.1	6597	68645	46977	1760	161342	80	20049
38-1-14	1	cpx-core	2	0.3	8753	88492	16153	2370	154490	52	1963
38-1-15	1	cpx-core	<LOD	<LOD	4587	91533	11042	<LOD	154492	52	1943
38-1-16	1	cpx-rim	19	0.8	12475	84654	16438	<LOD	134878	45	1722
38-1-5	2	cpx-core	3	0.7	6956	82087	39149	500	163830	76	12082
38-1-6	2	cpx-rim	5	0.8	8022	140715	37146	5288	96486	46	9412
38-2-6	1	cpx-core	3	<LOD	5056	94970	10321	131	169251	51	2201
38-2-7	1	cpx-rim	3	<LOD	6158	78339	27025	1460	144231	71	9850
38-2-8	1	cpx-core	7	0.5	13356	92816	18944	122	154418	53	2563
38-2-9	1	cpx-rim	6	1.5	7687	75608	48467	2165	148665	56	25433
38-3-1	2	cpx-core	3	<LOD	6863	85485	38253	458	168934	71	9341
38-3-2	2	cpx-rim	3	0.6	6460	74313	41977	1653	154215	73	15666
38-4-12	1	cpx-core	2	<LOD	5501	93522	12918	257	171232	54	2132
38-4-13	1	cpx-rim	3	0.8	9412	77533	42034	4834	156146	65	10855
38-4-18	2	cpx-rim	2	0.7	5565	75115	37267	1725	161195	69	13076
38-4-21	1	cpx-core	2	<LOD	5078	94229	12894	34	170433	55	2135
38-4-7	2	cpx-core	7	1.0	9936	82033	59592	5578	159001	63	21286
38-4-8	2	cpx-rim	3	0.4	9410	87119	41354	427	148590	64	8105
38-5-1	2	cpx-core	4	2.9	6168	70983	44947	820	161977	67	24768
38-5-2	2	cpx-rim	6	<LOD	7164	79929	52450	1780	172244	62	25520
38-5-3	2	cpx-core	6	2.7	10697	69678	57492	7675	126527	44	19005
38-5-4	2	cpx-rim	11	2.6	8417	74726	55069	5056	133099	47	19315
38-6-1	1	cpx-core	3	0.3	7753	88752	15077	1722	157594	56	2954
38-6-2	1	cpx-rim	3	0.3	5645	93175	11616	220	157750	53	1942
41-2-14	1	cpx-core	23	0.4	11112	88441	28623	<LOD	153487	64	1100
41-2-15	1	cpx-rim	24	0.3	11067	90366	27075	<LOD	158539	64	1058
41-3-12	1	cpx-core	30	0.4	10878	91120	26660	<LOD	160948	58	1427
41-3-13	1	cpx-rim	3	<LOD	4718	96756	20733	1222	155352	61	2476
41-3-3	2	cpx-rim	3	0.3	6399	88338	31701	1620	163824	68	3858
41-3-4	2	cpx-core	3	<LOD	5097	95816	18937	106	178532	63	1655

Sample	Type	Spot	V51_ppm	Cr53_ppm	Mn55_ppm	Co59_ppm	Ni60_ppm	Cu65_ppm	Zn66_ppm	Ga71_ppm
14-1-2	2	cpx-core	272	10476	762	23	389	4	26	10
14-1-3	2	cpx-rim	420	3997	615	22	265	11	34	16
14-2-8	2	cpx-core	291	11566	701	22	384	6	23	10
14-2-9	2	cpx-rim	335	2949	666	22	256	<LOD	28	12
14-3-3	2	cpx-core	222	9311	882	23	335	2	36	8
14-3-4	2	cpx-rim	269	10990	759	27	377	3	113	13
18-1-12	2	cpx-core	308	4135	636	29	212	6	27	15
18-1-13	2	cpx-rim	221	4367	585	31	217	<LOD	30	12
18-1-7	2	cpx-rim	523	643	809	41	195	<LOD	43	21
18-2-11	2	cpx-core	438	1383	686	32	218	<LOD	47	24
18-2-12	2	cpx-rim	331	2141	608	28	198	<LOD	37	21
18-2-15	1	cpx-core	213	1468	912	31	224	2	35	7
18-2-16	1	cpx-rim	226	1573	878	31	247	<LOD	33	7
18-2-17	1	cpx-core	284	3715	909	30	215	<LOD	36	12
18-2-18	1	cpx-rim	295	3792	706	31	230	<LOD	30	9
18-2-5	2	cpx-core	748	314	763	45	210	<LOD	60	25
30-1-13	2	cpx-core	246	10573	815	27	368	4	37	7
30-1-14	2	cpx-rim	152	9574	896	36	547	34	33	11
30-1-15	2	cpx-core	168	6741	895	41	656	31	45	11
30-1-16	2	cpx-rim	362	5320	672	24	286	<LOD	25	14
30-3-7	2	cpx-core	216	12153	882	38	520	5	48	8
30-3-8	2	cpx-rim	200	7450	729	24	288	12	28	11
38-1-11	2	cpx-core	436	2974	778	22	211	43	33	24
38-1-12	2	cpx-rim	279	4327	585	21	227	6	23	17
38-1-14	1	cpx-core	176	5238	962	20	315	<LOD	21	8
38-1-15	1	cpx-core	171	5432	991	20	287	<LOD	17	6
38-1-16	1	cpx-rim	154	5256	917	19	309	<LOD	23	7
38-1-5	2	cpx-core	210	8558	658	24	283	11	26	13
38-1-6	2	cpx-rim	185	10568	1202	71	994	23	123	14
38-2-6	1	cpx-core	194	6056	917	21	320	<LOD	20	8
38-2-7	1	cpx-rim	231	4091	698	21	241	5	20	9
38-2-8	1	cpx-core	186	5802	1021	22	346	<LOD	25	9
38-2-9	1	cpx-rim	424	3248	675	21	265	6	26	19
38-3-1	2	cpx-core	223	9283	678	26	328	61	54	13
38-3-2	2	cpx-rim	276	10218	705	33	320	39	77	16
38-4-12	1	cpx-core	183	5487	876	21	318	<LOD	21	7
38-4-13	1	cpx-rim	208	8778	601	20	297	15	35	13
38-4-18	2	cpx-rim	211	7267	553	18	257	42	19	11
38-4-21	1	cpx-core	185	5545	959	22	333	<LOD	23	8
38-4-7	2	cpx-core	317	5162	862	25	304	27	30	17
38-4-8	2	cpx-rim	138	16183	549	20	439	7	17	12
38-5-1	2	cpx-core	329	5422	557	21	272	4	26	19
38-5-2	2	cpx-rim	345	4772	725	24	289	13	25	20
38-5-3	2	cpx-core	249	3796	801	23	269	38	27	16
38-5-4	2	cpx-rim	246	3571	815	24	341	20	38	16
38-6-1	1	cpx-core	189	5948	758	23	365	3	23	8
38-6-2	1	cpx-rim	177	5845	866	24	386	8	25	7
41-2-14	1	cpx-core	201	7489	736	22	359	3	15	5
41-2-15	1	cpx-rim	198	6660	759	22	373	3	13	5
41-3-12	1	cpx-core	194	7596	787	22	376	4	16	6
41-3-13	1	cpx-rim	241	7021	729	28	469	32	21	4
41-3-3	2	cpx-rim	256	7933	794	22	318	6	19	6
41-3-4	2	cpx-core	208	8896	693	20	339	4	12	5

Sample	Type	Spot	Rb85_ppm	Sr88_ppm	Y89_ppm	Zr90_ppm	Nb93_ppm	Cs133_ppm	Ba137_ppm	La139_ppm
14-1-2	2	cpx-core	<LOD	127	16	61	0.5	<LOD	<LOD	2.32
14-1-3	2	cpx-rim	<LOD	250	39	349	9.8	<LOD	1.3	17.53
14-2-8	2	cpx-core	<LOD	116	15	52	0.8	<LOD	3.2	1.99
14-2-9	2	cpx-rim	<LOD	166	25	185	3.0	<LOD	3.4	7.08
14-3-3	2	cpx-core	1	230	18	118	1.9	<LOD	1.4	7.12
14-3-4	2	cpx-rim	2	149	18	104	4.7	<LOD	10.5	4.96
18-1-12	2	cpx-core	2	179	31	283	5.7	<LOD	9.2	21.64
18-1-13	2	cpx-rim	<LOD	112	13	109	2.2	<LOD	6.4	6.58
18-1-7	2	cpx-rim	1	193	35	337	6.9	<LOD	0.4	22.69
18-2-11	2	cpx-core	<LOD	206	40	393	9.8	<LOD	6.3	32.75
18-2-12	2	cpx-rim	<LOD	195	43	417	7.9	<LOD	0.3	34.27
18-2-15	1	cpx-core	<LOD	149	9	50	0.2	<LOD	<LOD	4.64
18-2-16	1	cpx-rim	<LOD	113	8	37	0.1	<LOD	<LOD	2.90
18-2-17	1	cpx-core	<LOD	152	12	84	0.4	<LOD	0.1	4.98
18-2-18	1	cpx-rim	<LOD	83	9	50	0.6	<LOD	0.1	2.64
18-2-5	2	cpx-core	<LOD	163	25	337	15.7	<LOD	9.0	20.43
30-1-13	2	cpx-core	8	158	23	33	6.2	0.1	52.1	10.08
30-1-14	2	cpx-rim	5	83	12	21	2.9	0.2	13.1	3.92
30-1-15	2	cpx-core	6	100	14	46	8.0	0.4	3.8	8.22
30-1-16	2	cpx-rim	1	163	44	302	5.9	<LOD	1.8	25.86
30-3-7	2	cpx-core	8	117	18	38	15.0	0.1	50.2	8.90
30-3-8	2	cpx-rim	7	129	27	182	11.5	0.1	43.1	17.57
38-1-11	2	cpx-core	13	210	53	554	45.0	0.1	66.0	34.24
38-1-12	2	cpx-rim	3	129	36	341	13.1	<LOD	56.1	16.65
38-1-14	1	cpx-core	8	188	26	268	0.7	0.1	33.1	8.19
38-1-15	1	cpx-core	<LOD	166	24	238	0.3	<LOD	<LOD	7.55
38-1-16	1	cpx-rim	<LOD	196	21	226	1.1	<LOD	<LOD	6.88
38-1-5	2	cpx-core	2	108	24	171	5.4	<LOD	8.6	7.59
38-1-6	2	cpx-rim	9	129	12	93	19.1	<LOD	161.2	7.11
38-2-6	1	cpx-core	<LOD	186	25	228	0.4	<LOD	1.8	9.18
38-2-7	1	cpx-rim	2	106	17	145	4.0	<LOD	39.6	3.62
38-2-8	1	cpx-core	0	228	25	269	1.3	<LOD	0.8	8.45
38-2-9	1	cpx-rim	5	222	49	518	33.0	<LOD	12.7	30.83
38-3-1	2	cpx-core	1	106	19	95	4.4	0.1	13.9	5.29
38-3-2	2	cpx-rim	3	160	21	160	10.9	<LOD	63.9	9.03
38-4-12	1	cpx-core	1	205	26	269	0.4	<LOD	3.5	8.52
38-4-13	1	cpx-rim	12	161	22	163	16.8	0.2	88.0	10.10
38-4-18	2	cpx-rim	2	116	20	150	7.7	<LOD	36.9	8.43
38-4-21	1	cpx-core	<LOD	184	27	273	0.4	<LOD	0.2	8.91
38-4-7	2	cpx-core	13	283	39	436	56.9	<LOD	46.6	23.03
38-4-8	2	cpx-rim	2	92	23	132	3.5	<LOD	8.7	3.79
38-5-1	2	cpx-core	1	157	61	591	25.8	<LOD	3.1	34.77
38-5-2	2	cpx-rim	3	210	62	619	51.6	<LOD	7.7	36.64
38-5-3	2	cpx-core	24	273	44	483	70.0	0.2	76.5	31.91
38-5-4	2	cpx-rim	9	228	47	481	53.2	<LOD	35.6	32.24
38-6-1	1	cpx-core	6	176	26	244	3.2	0.1	18.7	8.36
38-6-2	1	cpx-rim	1	164	25	243	0.7	<LOD	0.2	7.67
41-2-14	1	cpx-core	<LOD	223	17	145	1.2	<LOD	<LOD	12.85
41-2-15	1	cpx-rim	<LOD	233	18	142	1.1	<LOD	0.1	13.88
41-3-12	1	cpx-core	<LOD	242	17	170	1.2	<LOD	0.1	13.68
41-3-13	1	cpx-rim	3	68	16	79	6.9	<LOD	5.0	6.16
41-3-3	2	cpx-rim	5	96	20	80	16.7	<LOD	24.5	8.04
41-3-4	2	cpx-core	0	63	19	159	1.2	<LOD	0.1	11.22

Sample	Type	Spot	Ce140_ppm	Pr141_ppm	Nd146_ppm	Sm147_ppm	Eu153_ppm	Gd157_ppm	Tb159_ppm
14-1-2	2.00	cpx-core	12.21	2.61	15.88	5.32	1.74	5.61	0.76
14-1-3	2.00	cpx-rim	61.56	10.64	55.34	15.25	4.88	14.23	1.82
14-2-8	2.00	cpx-core	10.50	2.29	14.00	4.88	1.61	4.81	0.67
14-2-9	2.00	cpx-rim	30.44	5.83	33.97	9.46	2.98	9.06	1.17
14-3-3	2.00	cpx-core	25.23	4.51	22.77	6.30	2.17	6.44	0.90
14-3-4	2.00	cpx-rim	20.79	4.05	22.11	6.48	2.27	7.10	0.84
18-1-12	2.00	cpx-core	63.83	9.52	46.45	10.89	3.59	10.30	1.61
18-1-13	2.00	cpx-rim	20.56	3.54	18.82	5.01	1.49	4.91	0.58
18-1-7	2.00	cpx-rim	70.57	11.30	53.90	14.29	4.24	12.09	1.63
18-2-11	2.00	cpx-core	101.14	15.17	63.85	15.18	4.48	13.96	2.06
18-2-12	2.00	cpx-rim	104.00	15.08	68.93	17.43	4.45	15.39	2.05
18-2-15	1.00	cpx-core	16.16	2.62	12.93	3.26	1.04	3.25	0.47
18-2-16	1.00	cpx-rim	11.07	1.88	9.57	2.68	0.77	2.65	0.36
18-2-17	1.00	cpx-core	20.00	3.39	15.03	4.06	1.27	4.01	0.54
18-2-18	1.00	cpx-rim	10.35	1.87	10.98	3.70	0.95	3.80	0.44
18-2-5	2.00	cpx-core	64.77	9.43	44.28	11.17	3.35	9.97	1.08
30-1-13	2.00	cpx-core	34.06	5.63	26.49	6.46	2.35	5.96	0.80
30-1-14	2.00	cpx-rim	12.52	1.91	10.20	2.91	1.25	3.39	0.48
30-1-15	2.00	cpx-core	24.26	3.83	16.65	4.56	1.61	4.34	0.60
30-1-16	2.00	cpx-rim	84.59	13.20	61.62	15.47	4.02	14.42	1.89
30-3-7	2.00	cpx-core	26.09	4.06	19.60	5.07	1.61	4.98	0.72
30-3-8	2.00	cpx-rim	52.10	7.87	37.37	9.38	2.74	9.15	1.18
38-1-11	2.00	cpx-core	115.38	17.12	84.79	18.71	6.52	17.71	2.43
38-1-12	2.00	cpx-rim	58.34	10.09	48.97	13.36	3.92	12.11	1.63
38-1-14	1.00	cpx-core	32.24	5.80	29.88	7.98	2.73	7.63	1.04
38-1-15	1.00	cpx-core	30.69	5.42	27.15	7.01	2.54	7.30	0.95
38-1-16	1.00	cpx-rim	28.17	4.81	24.42	6.89	2.08	6.54	0.84
38-1-5	2.00	cpx-core	27.54	4.83	27.02	7.59	2.42	7.74	1.09
38-1-6	2.00	cpx-rim	19.18	2.97	14.75	4.14	1.34	4.29	0.49
38-2-6	1.00	cpx-core	37.78	6.80	31.49	7.75	2.75	7.42	1.07
38-2-7	1.00	cpx-rim	16.93	3.40	19.29	6.19	1.79	5.65	0.70
38-2-8	1.00	cpx-core	33.61	5.94	30.15	8.13	2.61	7.53	1.05
38-2-9	1.00	cpx-rim	101.67	16.11	80.16	17.31	5.61	18.21	2.19
38-3-1	2.00	cpx-core	18.81	3.35	18.46	6.20	1.94	6.24	0.88
38-3-2	2.00	cpx-rim	27.88	4.34	23.75	6.92	1.88	7.23	0.89
38-4-12	1.00	cpx-core	33.73	6.10	31.69	8.53	3.19	8.39	1.15
38-4-13	1.00	cpx-rim	31.44	5.21	26.77	8.00	2.74	7.74	1.03
38-4-18	2.00	cpx-rim	30.25	5.00	25.70	7.34	2.55	7.04	0.95
38-4-21	1.00	cpx-core	34.60	6.25	33.10	8.96	3.35	8.76	1.21
38-4-7	2.00	cpx-core	78.55	12.81	61.21	16.52	5.01	13.68	1.70
38-4-8	2.00	cpx-rim	16.61	3.42	21.05	7.12	2.58	7.16	1.05
38-5-1	2.00	cpx-core	111.29	18.41	84.99	21.27	6.15	19.87	2.51
38-5-2	2.00	cpx-rim	113.45	17.86	88.25	23.98	6.79	20.01	2.86
38-5-3	2.00	cpx-core	98.10	15.45	68.22	16.47	4.44	15.42	2.01
38-5-4	2.00	cpx-rim	100.27	15.54	74.54	17.14	5.69	15.79	2.08
38-6-1	1.00	cpx-core	31.12	5.49	29.82	8.37	2.74	8.21	1.05
38-6-2	1.00	cpx-rim	31.04	5.67	29.17	8.06	2.76	7.28	1.07
41-2-14	1.00	cpx-core	40.45	5.85	23.67	5.18	1.50	4.39	0.66
41-2-15	1.00	cpx-rim	42.09	5.88	25.01	5.28	1.51	4.61	0.65
41-3-12	1.00	cpx-core	42.85	6.10	25.66	5.26	1.58	5.02	0.64
41-3-13	1.00	cpx-rim	23.94	3.65	16.61	4.63	1.28	4.29	0.59
41-3-3	2.00	cpx-rim	30.61	5.03	22.92	5.56	2.02	5.52	0.79
41-3-4	2.00	cpx-core	40.50	6.08	26.11	5.45	2.57	5.02	0.67

Sample	Type	Spot	Dy163_ppm	Ho165_ppm	Er166_ppm	Tm169_ppm	Yb173_ppm	Lu175_ppm	Hf178_ppm
14-1-3	2.00	cpx-rim	8.45	1.53	3.17	0.37	1.89	0.30	8.99
14-2-9	2.00	cpx-rim	6.30	0.95	2.06	0.17	1.30	0.20	6.28
14-3-3	2.00	cpx-core	4.58	0.75	1.68	0.17	1.28	0.16	3.10
14-3-4	2.00	cpx-rim	4.20	0.68	1.42	0.17	0.90	0.12	3.14
41-3-13	1.00	cpx-rim	3.04	0.62	1.56	0.20	1.18	0.17	2.39
38-1-15	1.00	cpx-core	5.39	0.97	2.37	0.27	1.96	0.22	6.06
38-1-16	1.00	cpx-rim	4.81	0.75	2.06	0.28	1.37	0.24	6.63
38-2-7	1.00	cpx-rim	4.91	0.73	1.65	0.19	0.93	0.12	5.29
38-4-7	2.00	cpx-core	8.90	1.70	3.98	0.42	2.26	0.34	12.29
38-5-1	2.00	cpx-core	14.75	2.32	5.14	0.62	3.56	0.41	17.38
38-5-2	2.00	cpx-rim	16.41	2.52	6.26	0.70	4.05	0.58	18.30
38-5-3	2.00	cpx-core	11.20	1.75	3.47	0.43	2.68	0.43	13.81
38-5-4	2.00	cpx-rim	12.06	1.86	4.43	0.57	2.93	0.35	13.51
18-1-6	2.00	cpx-core	2.26	0.27	0.84	0.06	0.69	<LOD	1.10
18-1-7	2.00	cpx-rim	8.45	1.32	2.69	0.38	2.16	0.30	10.44
18-1-12	2.00	cpx-core	7.59	1.26	3.61	0.35	2.33	0.34	8.07
18-2-18	1.00	cpx-rim	2.44	0.39	0.83	0.10	0.66	0.06	1.80
18-2-6	2.00	cpx-rim	0.10	0.02	0.19	<LOD	0.48	0.03	<LOD
18-2-5	2.00	cpx-core	7.30	1.02	2.77	0.40	1.88	0.18	8.92
18-2-11	2.00	cpx-core	10.35	1.66	4.06	0.39	2.47	0.32	10.96
18-2-12	2.00	cpx-rim	11.57	1.86	4.57	0.50	2.13	0.34	11.60
14-1-2	2.00	cpx-core	4.11	0.73	1.44	0.18	0.87	0.13	2.76
14-2-8	2.00	cpx-core	4.17	0.67	1.28	0.14	0.86	0.09	2.38
41-2-14	1.00	cpx-core	3.75	0.63	1.74	0.24	1.38	0.20	2.51
41-2-15	1.00	cpx-rim	3.70	0.69	1.79	0.22	1.30	0.22	2.78
41-3-12	1.00	cpx-core	3.84	0.67	1.86	0.22	1.52	0.19	4.14
41-3-3	2.00	cpx-rim	4.68	0.84	2.21	0.29	1.59	0.21	2.50
41-3-4	2.00	cpx-core	3.92	0.77	1.93	0.29	1.55	0.24	4.66
18-2-15	1.00	cpx-core	2.41	0.45	0.94	0.12	0.66	0.08	1.42
18-2-16	1.00	cpx-rim	2.09	0.36	0.72	0.07	0.30	0.04	1.10
18-2-17	1.00	cpx-core	2.98	0.46	1.05	0.13	0.78	0.09	2.46
30-1-16	2.00	cpx-rim	10.82	1.69	4.23	0.49	2.85	0.37	9.00
30-1-15	2.00	cpx-core	3.43	0.65	1.30	0.17	0.93	0.13	1.21
30-1-13	2.00	cpx-core	4.78	0.81	2.28	0.31	1.60	0.26	0.70
30-1-14	2.00	cpx-rim	2.89	0.51	1.18	0.12	0.75	0.09	0.96
30-3-7	2.00	cpx-core	3.62	0.68	1.79	0.22	1.48	0.20	0.91
30-3-8	2.00	cpx-rim	6.11	1.08	2.61	0.28	1.94	0.23	5.22
38-1-14	1.00	cpx-core	5.91	1.02	2.53	0.29	2.06	0.23	7.91
38-1-5	2.00	cpx-core	5.77	0.98	2.22	0.26	1.29	0.18	6.72
38-1-6	2.00	cpx-rim	3.10	0.50	1.25	0.14	0.74	0.10	3.45
38-1-12	2.00	cpx-rim	9.03	1.40	3.41	0.41	1.98	0.26	11.78
38-1-11	2.00	cpx-core	13.05	2.40	5.42	0.66	3.82	0.41	15.79
38-2-6	1.00	cpx-core	6.29	1.02	2.51	0.25	1.80	0.24	6.54
38-2-8	1.00	cpx-core	5.91	0.98	2.64	0.29	1.98	0.25	7.76
38-3-1	2.00	cpx-core	4.47	0.81	1.74	0.21	1.27	0.14	4.05
38-3-2	2.00	cpx-rim	4.42	0.82	1.96	0.20	1.07	0.13	5.78
38-4-21	1.00	cpx-core	6.47	1.12	2.81	0.30	2.09	0.26	8.45
38-4-13	1.00	cpx-rim	5.62	0.92	2.43	0.23	1.29	0.19	5.64
38-4-12	1.00	cpx-core	6.08	1.02	2.63	0.38	2.07	0.28	7.99
38-4-8	2.00	cpx-rim	5.62	0.99	2.52	0.27	1.50	0.20	5.83
38-4-18	2.00	cpx-rim	5.47	0.92	2.33	0.23	0.92	0.12	6.12
38-6-1	1.00	cpx-core	6.29	1.03	2.50	0.28	1.92	0.23	7.50
38-6-2	1.00	cpx-rim	6.10	1.03	2.69	0.31	1.99	0.23	7.19

Sample	Type	Spot	Ta181_ppm	Pb208_ppm	Th232_ppm	U238_ppm
14-1-3	2.00	cpx-rim	1.40	0.32	0.46	0.06
14-2-9	2.00	cpx-rim	0.67	<LOD	0.10	0.04
14-3-3	2.00	cpx-core	0.16	0.39	0.10	0.04
14-3-4	2.00	cpx-rim	0.40	0.54	0.06	0.03
41-3-13	1.00	cpx-rim	0.35	0.43	0.24	0.04
38-1-15	1.00	cpx-core	0.04	<LOD	0.03	<LOD
38-1-16	1.00	cpx-rim	0.12	0.22	0.18	0.06
38-2-7	1.00	cpx-rim	0.67	0.21	0.02	0.07
38-4-7	2.00	cpx-core	4.38	1.89	1.90	0.44
38-5-1	2.00	cpx-core	3.02	0.61	1.20	0.20
38-5-2	2.00	cpx-rim	4.59	0.55	2.61	0.61
38-5-3	2.00	cpx-core	5.50	1.61	3.93	1.49
38-5-4	2.00	cpx-rim	4.37	1.60	2.17	0.50
18-1-6	2.00	cpx-core	0.05	<LOD	<LOD	<LOD
18-1-7	2.00	cpx-rim	1.63	<LOD	0.65	0.05
18-1-12	2.00	cpx-core	1.02	<LOD	0.69	0.15
18-2-18	1.00	cpx-rim	0.13	<LOD	0.04	<LOD
18-2-6	2.00	cpx-rim	0.03	<LOD	<LOD	<LOD
18-2-5	2.00	cpx-core	2.89	<LOD	1.24	0.10
18-2-11	2.00	cpx-core	1.82	<LOD	0.67	0.13
18-2-12	2.00	cpx-rim	1.49	0.22	0.60	0.14
14-1-2	2.00	cpx-core	0.07	<LOD	0.01	<LOD
14-2-8	2.00	cpx-core	0.10	<LOD	0.02	<LOD
41-2-14	1.00	cpx-core	0.24	0.45	0.81	0.20
41-2-15	1.00	cpx-rim	0.22	0.53	0.88	0.19
41-3-12	1.00	cpx-core	0.23	0.64	0.80	0.15
41-3-3	2.00	cpx-rim	1.08	0.61	0.39	0.15
41-3-4	2.00	cpx-core	0.16	0.20	0.19	0.03
18-2-15	1.00	cpx-core	0.02	0.24	0.11	0.01
18-2-16	1.00	cpx-rim	0.02	0.17	0.07	<LOD
18-2-17	1.00	cpx-core	0.07	0.28	0.23	0.04
30-1-16	2.00	cpx-rim	0.88	0.18	0.43	0.07
30-1-15	2.00	cpx-core	0.41	0.36	1.29	0.23
30-1-13	2.00	cpx-core	0.27	0.45	0.26	0.16
30-1-14	2.00	cpx-rim	0.08	0.46	0.14	0.08
30-3-7	2.00	cpx-core	0.59	0.58	1.06	0.46
30-3-8	2.00	cpx-rim	0.95	0.75	0.87	0.31
38-1-14	1.00	cpx-core	0.13	0.30	0.18	0.02
38-1-5	2.00	cpx-core	0.91	0.23	0.24	0.05
38-1-6	2.00	cpx-rim	1.05	0.76	1.89	0.48
38-1-12	2.00	cpx-rim	1.98	0.28	0.44	0.14
38-1-11	2.00	cpx-core	5.05	0.51	2.36	0.69
38-2-6	1.00	cpx-core	0.09	<LOD	0.06	<LOD
38-2-8	1.00	cpx-core	0.20	0.20	0.20	0.04
38-3-1	2.00	cpx-core	0.43	0.45	0.37	0.09
38-3-2	2.00	cpx-rim	1.05	0.96	0.77	0.23
38-4-21	1.00	cpx-core	0.09	0.11	0.08	0.01
38-4-13	1.00	cpx-rim	1.29	1.40	0.85	0.31
38-4-12	1.00	cpx-core	0.10	0.09	0.09	0.01
38-4-8	2.00	cpx-rim	0.60	<LOD	0.07	0.04
38-4-18	2.00	cpx-rim	0.90	10.58	0.33	0.14
38-6-1	1.00	cpx-core	0.31	0.25	0.13	0.04
38-6-2	1.00	cpx-rim	0.09	0.08	0.09	0.02

Sample	Type	Spot	Li7_ppm	Be9_ppm	Na23_ppm	Mg24_ppm	Al27_ppm	K39_ppm	Ca42_ppm	Sc45_ppm
18-1-1	2	pl-core	<LOD	<LOD	51740	264	143985	6596	45493	4
18-1-5	2	pl-rim	<LOD	<LOD	42463	358	154564	4169	57923	4
18-2-1	2	pl-core	<LOD	<LOD	46603	544	137108	5275	58549	4
18-2-2	2	pl-rim	<LOD	0.2	47472	1048	140081	7136	64078	4
18-2-3	2	pl-core	<LOD	<LOD	50776	308	144612	5480	64435	5
18-2-4	2	pl-rim	<LOD	<LOD	52225	186	141842	5986	59602	5
30-1-10	2	pl-rim	<LOD	0.5	43612	704	141265	6555	59156	4
30-1-7	2	pl-core	<LOD	<LOD	46763	471	139439	7120	55897	4
30-1-8	2	pl-rim	<LOD	<LOD	49401	143	140298	7813	51488	4
30-1-9	2	pl-core	<LOD	0.4	42761	366	142288	5633	60211	4
30-3-1	2	pl-core	<LOD	<LOD	42084	205	143276	5050	63380	4
30-3-2	2	pl-rim	<LOD	<LOD	47037	193	132434	7638	47778	3
30-3-3	2	pl-core	<LOD	<LOD	42926	201	139665	5518	59505	3
30-3-4	2	pl-rim	<LOD	<LOD	42117	599	136633	5299	59307	3
38-1-10	2	pl-rim	2	1.6	42854	2958	143530	10567	63511	5
38-1-9	2	pl-core	2	<LOD	40075	1469	140439	5355	68258	5
38-3-11	2	pl-core	<LOD	0.5	37108	231	145923	3795	70313	4
38-3-16	2	pl-rim	<LOD	0.4	42303	458	146732	5503	61958	4
41-2-12	2	pl	<LOD	<LOD	41568	17449	114785	25532	33034	12
41-2-13	2	pl	<LOD	<LOD	53579	314	119355	24046	22994	5
41-3-2	2	pl	<LOD	<LOD	52452	371	143360	6890	52876	4

Sample	Type	Spot	Ti47_ppm	V51_ppm	Cr53_ppm	Mn55_ppm	Co59_ppm	Ni60_ppm	Cu65_ppm	Zn66_ppm
18-1-1	2	pl-core	845	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-1-5	2	pl-rim	665	1	<LOD	7	<LOD	<LOD	<LOD	<LOD
18-2-1	2	pl-core	1180	1	<LOD	7	<LOD	<LOD	4	7
18-2-2	2	pl-rim	1028	1	<LOD	17	<LOD	<LOD	<LOD	<LOD
18-2-3	2	pl-core	1283	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-4	2	pl-rim	1745	1	<LOD	<LOD	<LOD	<LOD	<LOD	3
30-1-10	2	pl-rim	1107	2	16	11	<LOD	2	<LOD	<LOD
30-1-7	2	pl-core	1228	1	<LOD	8	<LOD	<LOD	3	<LOD
30-1-8	2	pl-rim	1437	1	<LOD	4	<LOD	<LOD	<LOD	<LOD
30-1-9	2	pl-core	1340	1	<LOD	6	<LOD	<LOD	<LOD	<LOD
30-3-1	2	pl-core	1095	1	<LOD	4	<LOD	<LOD	<LOD	<LOD
30-3-2	2	pl-rim	1253	1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-3-3	2	pl-core	1040	1	<LOD	5	<LOD	<LOD	<LOD	3
30-3-4	2	pl-rim	1026	1	<LOD	8	<LOD	3	4	<LOD
38-1-10	2	pl-rim	3421	11	<LOD	61	1	9	22	6
38-1-9	2	pl-core	3188	9	<LOD	86	1	5	13	8
38-3-11	2	pl-core	925	1	<LOD	8	<LOD	1	<LOD	2
38-3-16	2	pl-rim	1259	<LOD	<LOD	12	<LOD	1	<LOD	<LOD
41-2-12	2	pl	5303	35	<LOD	234	17	240	26	8
41-2-13	2	pl	1619	2	<LOD	5	<LOD	2	<LOD	<LOD
41-3-2	2	pl	1506	1	<LOD	8	<LOD	<LOD	<LOD	<LOD

Sample	Type	Spot	Ga71_ppm	Rb85_ppm	Sr88_ppm	Y89_ppm	Zr90_ppm	Nb93_ppm	Cs133_ppm
18-1-1	2	pl-core	22	2	3633	0	0	0.1	<LOD
18-1-5	2	pl-rim	22	<LOD	3232	0	0	0.1	<LOD
18-2-1	2	pl-core	25	2	5588	0	0	0.2	<LOD
18-2-2	2	pl-rim	27	14	4726	0	8	1.9	<LOD
18-2-3	2	pl-core	28	3	5341	0	1	0.6	<LOD
18-2-4	2	pl-rim	33	2	5159	0	0	<LOD	<LOD
30-1-10	2	pl-rim	22	4	3483	0	1	1.0	<LOD
30-1-7	2	pl-core	22	4	3388	0	2	1.1	<LOD
30-1-8	2	pl-rim	23	2	3387	0	0	0.1	<LOD
30-1-9	2	pl-core	23	2	4076	0	0	0.1	<LOD
30-3-1	2	pl-core	24	2	3287	0	0	0.1	<LOD
30-3-2	2	pl-rim	22	3	3010	0	0	0.2	<LOD
30-3-3	2	pl-core	23	2	3224	0	1	0.2	<LOD
30-3-4	2	pl-rim	22	2	3116	0	1	0.2	<LOD
38-1-10	2	pl-rim	23	24	2566	4	105	60.1	0.4
38-1-9	2	pl-core	26	9	3035	2	56	44.1	<LOD
38-3-11	2	pl-core	21	1	2939	0	0	0.3	<LOD
38-3-16	2	pl-rim	25	2	2967	0	2	0.7	<LOD
41-2-12	2	pl	19	87	495	32	600	482.2	<LOD
41-2-13	2	pl	18	27	768	0	2	0.7	<LOD
41-3-2	2	pl	23	4	1663	0	1	0.7	<LOD

Sample	Type	Spot	Ba137_ppm	La139_ppm	Ce140_ppm	Pr141_ppm	Nd146_ppm	Sm147_ppm	Eu153_ppm
18-1-1	2	pl-core	1769.9	18.87	19.59	1.21	3.65	<LOD	1.44
18-1-5	2	pl-rim	827.5	12.91	15.55	1.25	3.08	0.26	1.32
18-2-1	2	pl-core	1742.4	16.32	18.40	1.18	2.88	0.45	1.92
18-2-2	2	pl-rim	1815.2	30.03	30.59	2.07	5.34	0.39	1.70
18-2-3	2	pl-core	2378.5	28.35	30.30	2.14	4.21	0.54	1.58
18-2-4	2	pl-rim	2759.7	30.96	32.68	2.25	5.03	0.62	2.17
30-1-10	2	pl-rim	1022.2	17.08	19.79	1.47	3.78	0.40	1.84
30-1-7	2	pl-core	1382.6	21.98	23.41	1.75	3.81	0.47	2.07
30-1-8	2	pl-rim	1854.4	28.20	28.33	1.92	5.29	0.41	2.36
30-1-9	2	pl-core	1728.7	25.70	28.57	2.13	5.31	0.27	2.25
30-3-1	2	pl-core	986.3	20.95	24.23	1.79	4.70	0.55	1.76
30-3-2	2	pl-rim	1920.2	28.84	29.62	2.04	5.02	0.34	2.61
30-3-3	2	pl-core	1242.4	21.02	24.56	1.68	4.85	0.39	1.93
30-3-4	2	pl-rim	1064.6	19.85	23.47	1.57	4.86	0.33	2.18
38-1-10	2	pl-rim	1635.8	32.80	51.36	4.41	12.50	1.77	2.43
38-1-9	2	pl-core	1558.6	28.76	39.27	3.14	8.76	0.82	1.67
38-3-11	2	pl-core	842.2	20.92	24.37	1.99	5.30	0.31	1.99
38-3-16	2	pl-rim	1449.7	25.63	28.40	2.23	5.15	0.48	2.33
41-2-12	2	pl	443.7	54.85	121.38	11.69	43.90	6.75	1.55
41-2-13	2	pl	920.4	16.56	18.30	1.23	3.42	0.14	1.53
41-3-2	2	pl	1275.4	29.70	35.17	2.43	6.68	0.58	2.19

Sample	Type	Spot	Gd157_ppm	Tb159_ppm	Dy163_ppm	Ho165_ppm	Er166_ppm	Tm169_ppm	Yb173_ppm
18-1-1	2	pl-core	0.12	<LOD	0.05	<LOD	<LOD	<LOD	<LOD
18-1-5	2	pl-rim	0.15	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-1	2	pl-core	0.24	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18-2-2	2	pl-rim	0.10	0.03	<LOD	0.02	<LOD	<LOD	<LOD
18-2-3	2	pl-core	0.23	0.01	0.05	<LOD	0.07	<LOD	<LOD
18-2-4	2	pl-rim	0.09	<LOD	0.05	<LOD	<LOD	<LOD	<LOD
30-1-10	2	pl-rim	<LOD	0.01	0.17	0.01	<LOD	<LOD	<LOD
30-1-7	2	pl-core	0.15	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
30-1-8	2	pl-rim	0.15	0.02	0.05	<LOD	<LOD	<LOD	<LOD
30-1-9	2	pl-core	0.14	0.01	<LOD	<LOD	0.02	<LOD	<LOD
30-3-1	2	pl-core	0.22	0.02	0.09	<LOD	<LOD	<LOD	<LOD
30-3-2	2	pl-rim	<LOD	0.01	0.04	<LOD	<LOD	<LOD	<LOD
30-3-3	2	pl-core	0.13	0.01	0.07	<LOD	<LOD	<LOD	<LOD
30-3-4	2	pl-rim	0.12	0.03	0.08	0.01	<LOD	<LOD	<LOD
38-1-10	2	pl-rim	1.24	0.16	0.91	0.13	0.36	0.08	0.36
38-1-9	2	pl-core	0.56	0.10	0.44	0.07	0.11	<LOD	0.24
38-3-11	2	pl-core	0.11	0.01	0.05	<LOD	<LOD	<LOD	<LOD
38-3-16	2	pl-rim	0.19	0.02	<LOD	<LOD	<LOD	<LOD	<LOD
41-2-12	2	pl	5.45	1.02	6.38	1.16	3.48	0.55	2.86
41-2-13	2	pl	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
41-3-2	2	pl	<LOD	<LOD	0.05	0.02	<LOD	<LOD	<LOD

Sample	Type	Spot	Lu175_ppm	Hf178_ppm	Ta181_ppm	Pb208_ppm	Th232_ppm	U238_ppm
18-1-1	2	pl-core	<LOD	<LOD	<LOD	1.24	<LOD	<LOD
18-1-5	2	pl-rim	<LOD	<LOD	<LOD	1.54	<LOD	<LOD
18-2-1	2	pl-core	<LOD	<LOD	<LOD	1.50	<LOD	<LOD
18-2-2	2	pl-rim	<LOD	0.09	<LOD	1.37	<LOD	0.06
18-2-3	2	pl-core	<LOD	<LOD	0.02	1.90	<LOD	0.01
18-2-4	2	pl-rim	<LOD	0.04	<LOD	1.92	<LOD	<LOD
30-1-10	2	pl-rim	<LOD	<LOD	0.06	1.79	<LOD	0.03
30-1-7	2	pl-core	<LOD	0.06	0.03	2.00	<LOD	0.04
30-1-8	2	pl-rim	<LOD	<LOD	<LOD	2.14	<LOD	<LOD
30-1-9	2	pl-core	<LOD	<LOD	<LOD	1.56	<LOD	<LOD
30-3-1	2	pl-core	<LOD	<LOD	<LOD	1.79	<LOD	<LOD
30-3-2	2	pl-rim	<LOD	<LOD	<LOD	2.16	<LOD	<LOD
30-3-3	2	pl-core	<LOD	<LOD	<LOD	2.15	<LOD	<LOD
30-3-4	2	pl-rim	<LOD	<LOD	0.02	1.66	<LOD	<LOD
38-1-10	2	pl-rim	0.03	1.47	3.15	3.47	3.36	1.45
38-1-9	2	pl-core	0.02	0.77	1.83	2.60	1.75	0.85
38-3-11	2	pl-core	<LOD	<LOD	0.02	1.13	<LOD	0.02
38-3-16	2	pl-rim	<LOD	0.04	0.05	1.43	0.01	0.02
41-2-12	2	pl	0.36	8.15	20.31	5.25	47.94	18.84
41-2-13	2	pl	<LOD	0.05	0.07	2.89	<LOD	<LOD
41-3-2	2	pl	<LOD	<LOD	0.02	2.12	<LOD	0.02

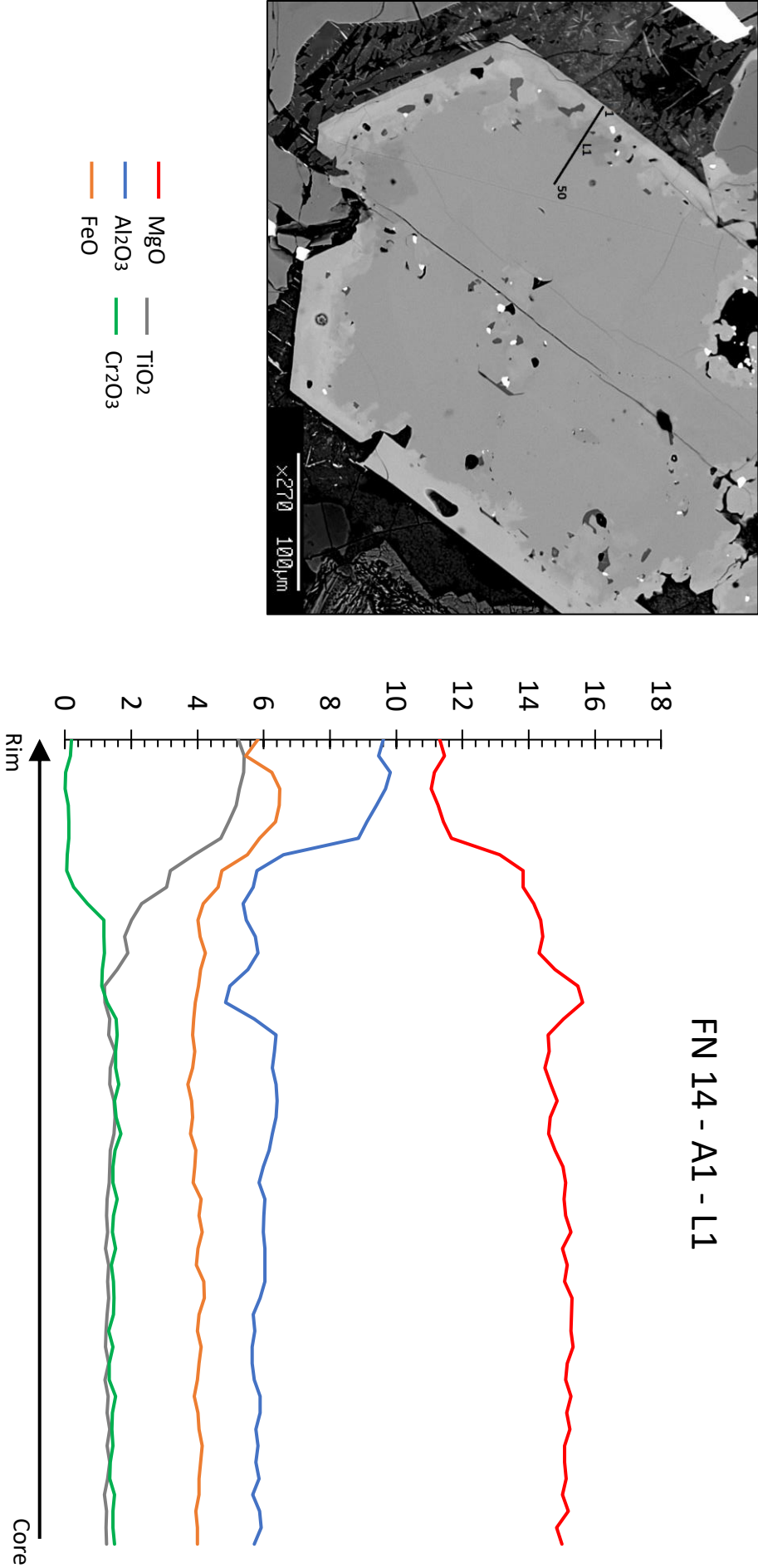
Sample	Li7_ppm	Be9_ppm	Na23_ppm	Mg24_ppm	Al27_ppm	K39_ppm	Ca42_ppm	Sc45_ppm	Ti47_ppm
14-2-VTR-3	6	2.8	79388	3860	125716	28283	7009	6	10464
14-2-VTR-4	16	3.0	56588	32137	117354	27372	11293	6	11385
14-2-VTR-5	30	2.9	47563	69636	120319	17138	10657	7	13165
14-3-VTR-1	28	1.1	2796	98988	65811	6770	5062	4	7411
18-1-VTR-1	16	3.8	63667	4825	112441	45665	11752	6	8007
18-1-VTR-2	18	3.8	54939	3360	107820	67791	8064	7	6958
18-1-VTR-3	21	4.3	64651	3229	111425	56177	7421	5	6920
18-2-VTR-1	23	4.2	57001	4916	109623	61689	9355	6	8462
18-2-VTR-2	16	4.8	65534	4254	110461	47116	11185	6	8448
18-2-VTR-3	4	6.0	59846	10432	94330	41309	25767	8	6531
30-1-VTR-1	18	3.5	60780	4646	107353	53058	7427	7	9573
30-1-VTR-2	20	3.6	65308	4721	108303	49671	6811	7	9917
30-1-VTR-3	21	3.2	64858	4377	107848	50945	5688	7	10308
30-1-VTR-4	16	4.1	63310	3748	111889	53819	4828	7	10736
30-3-VTR-1	17	5.1	60135	4956	109826	57974	8809	7	9957
30-3-VTR-2	15	4.3	57382	5339	109327	55588	8906	7	9260
30-3-VTR-3	17	4.7	56696	4741	109461	57781	8267	7	9003
38-1-VTR-1	14	4.3	68703	4617	113220	30821	10400	7	7894
38-1-VTR-2	16	3.4	44979	14325	108406	56043	9600	7	10999
38-1-VTR-3	18	3.9	54950	4414	111310	64290	9255	7	8665
38-1-VTR-4	18	3.7	56664	4308	110119	54754	9416	6	8958
38-2-VTR-1	6	4.7	47736	8106	117568	52711	12130	7	11296
38-2-VTR-2	16	4.0	61472	5186	118864	48314	11240	7	11058
38-2-VTR-3	10	3.6	52167	6356	116518	48183	12335	7	10937
38-2-VTR-4	9	2.8	42823	21588	103464	35117	10704	6	10328
38-3-VTR-1	19	3.8	57969	4658	110559	56496	9322	7	8565
38-3-VTR-2	5	4.6	65316	11599	111477	14175	25040	7	9036
38-3-VTR-3	12	3.7	48165	6074	107920	56867	8347	7	8538
38-4-VTR-1	7	3.0	54152	4339	131572	57270	8901	6	10141
38-4-VTR-2	9	3.3	46114	7831	117275	53612	11712	7	9853
38-4-VTR-3	10	3.0	58180	5285	123453	53170	11484	7	9919
38-5-VTR-1	6	4.0	40466	10466	101498	52474	7216	5	9003
38-5-VTR-2	9	3.1	40124	13371	100616	50580	7336	6	8744
38-5-VTR-3	11	1.8	34242	26993	89824	42768	6525	5	7791
41-2-VTR-1	6	0.8	25561	108826	66264	10082	48108	59	5641
41-2-VTR-2	2	1.9	34711	45270	124339	6235	54651	34	7432
41-2-VTR-3	3	4.5	29440	63361	95010	5142	77196	77	5777
41-3-VTR-1	13	3.8	10732	73031	90229	52145	9415	14	8679
41-3-VTR-2	15	2.9	17274	63832	100346	47556	14797	13	10398

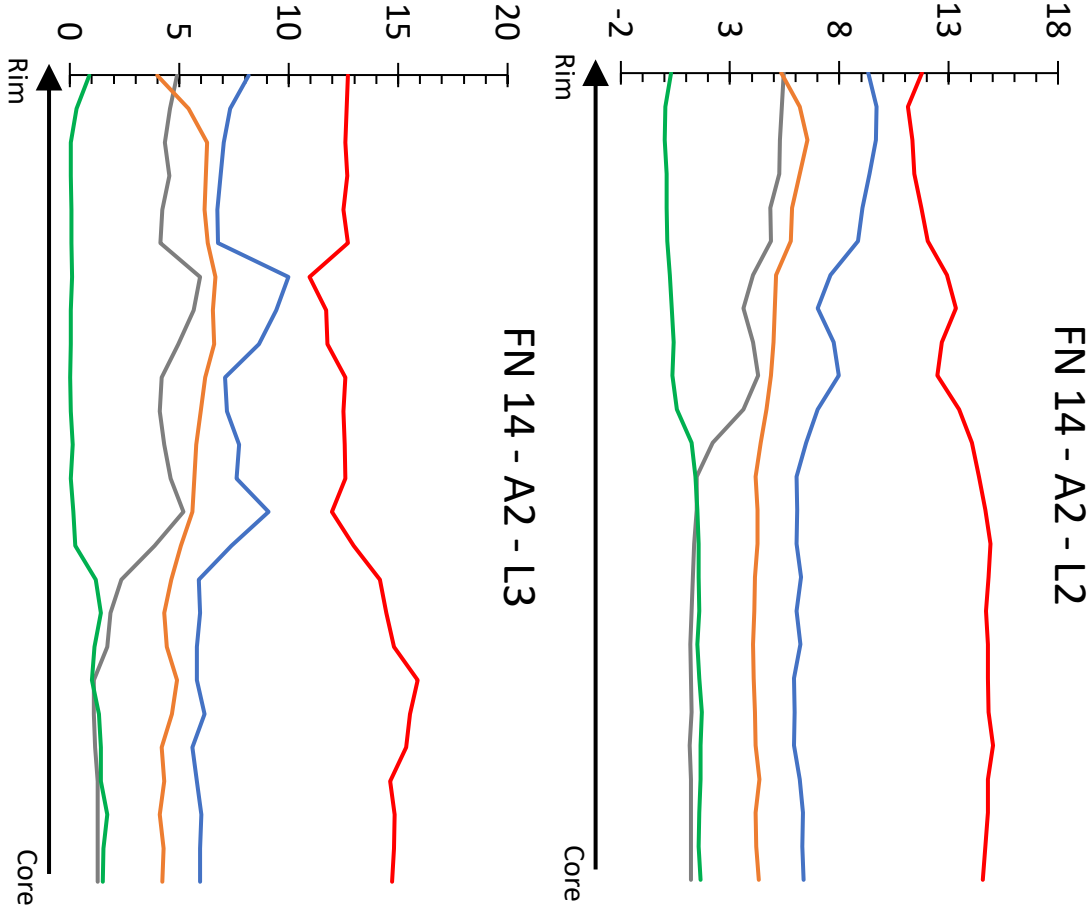
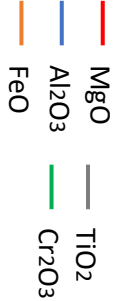
Sample	V51_ppm	Cr53_ppm	Mn55_ppm	Co59_ppm	Ni60_ppm	Cu65_ppm	Zn66_ppm	Ga71_ppm	Rb85_ppm
14-2-VTR-3	50	<LOD	249	4	11	27	25	22	99
14-2-VTR-4	60	<LOD	373	6	70	42	28	18	103
14-2-VTR-5	67	<LOD	663	13	108	46	39	19	39
14-3-VTR-1	36	<LOD	1145	41	260	20	47	8	20
18-1-VTR-1	47	<LOD	230	6	<LOD	26	30	24	156
18-1-VTR-2	39	<LOD	228	5	<LOD	27	29	25	204
18-1-VTR-3	31	<LOD	196	5	<LOD	25	32	24	189
18-2-VTR-1	42	<LOD	250	6	4	23	36	24	196
18-2-VTR-2	42	<LOD	256	5	1	20	39	26	171
18-2-VTR-3	39	<LOD	359	7	9	86	21	26	193
30-1-VTR-1	61	4	190	4	1	7	25	23	163
30-1-VTR-2	55	6	180	4	2	4	23	22	156
30-1-VTR-3	57	<LOD	182	3	1	5	26	23	156
30-1-VTR-4	54	<LOD	191	4	2	16	24	23	157
30-3-VTR-1	48	<LOD	220	4	2	16	28	23	155
30-3-VTR-2	51	4	217	4	6	13	26	23	161
30-3-VTR-3	46	5	207	4	1	7	25	23	183
38-1-VTR-1	28	<LOD	221	3	15	50	21	22	109
38-1-VTR-2	43	4	711	8	84	67	40	20	120
38-1-VTR-3	32	<LOD	232	4	1	7	34	23	206
38-1-VTR-4	35	<LOD	217	4	1	17	30	23	164
38-2-VTR-1	60	<LOD	298	6	13	17	29	25	153
38-2-VTR-2	56	<LOD	207	4	4	16	27	24	148
38-2-VTR-3	57	3	222	5	10	11	26	25	139
38-2-VTR-4	53	<LOD	607	13	112	38	26	20	119
38-3-VTR-1	32	3	239	5	1	16	34	24	191
38-3-VTR-2	39	3	525	7	53	87	31	25	22
38-3-VTR-3	30	<LOD	303	5	11	43	36	25	205
38-4-VTR-1	40	<LOD	216	4	5	30	23	22	163
38-4-VTR-2	45	<LOD	278	5	14	15	21	21	177
38-4-VTR-3	40	16	209	4	10	14	17	22	153
38-5-VTR-1	45	<LOD	383	8	43	17	22	23	160
38-5-VTR-2	43	<LOD	507	9	49	17	25	23	162
38-5-VTR-3	38	<LOD	892	15	121	17	31	19	133
41-2-VTR-1	195	6659	745	52	887	7	48	11	12
41-2-VTR-2	497	20916	723	43	581	23	168	27	6
41-2-VTR-3	199	2077	601	26	462	62	16	13	5
41-3-VTR-1	50	4	2624	43	819	100	15	20	317
41-3-VTR-2	49	21	2514	37	611	40	16	21	185

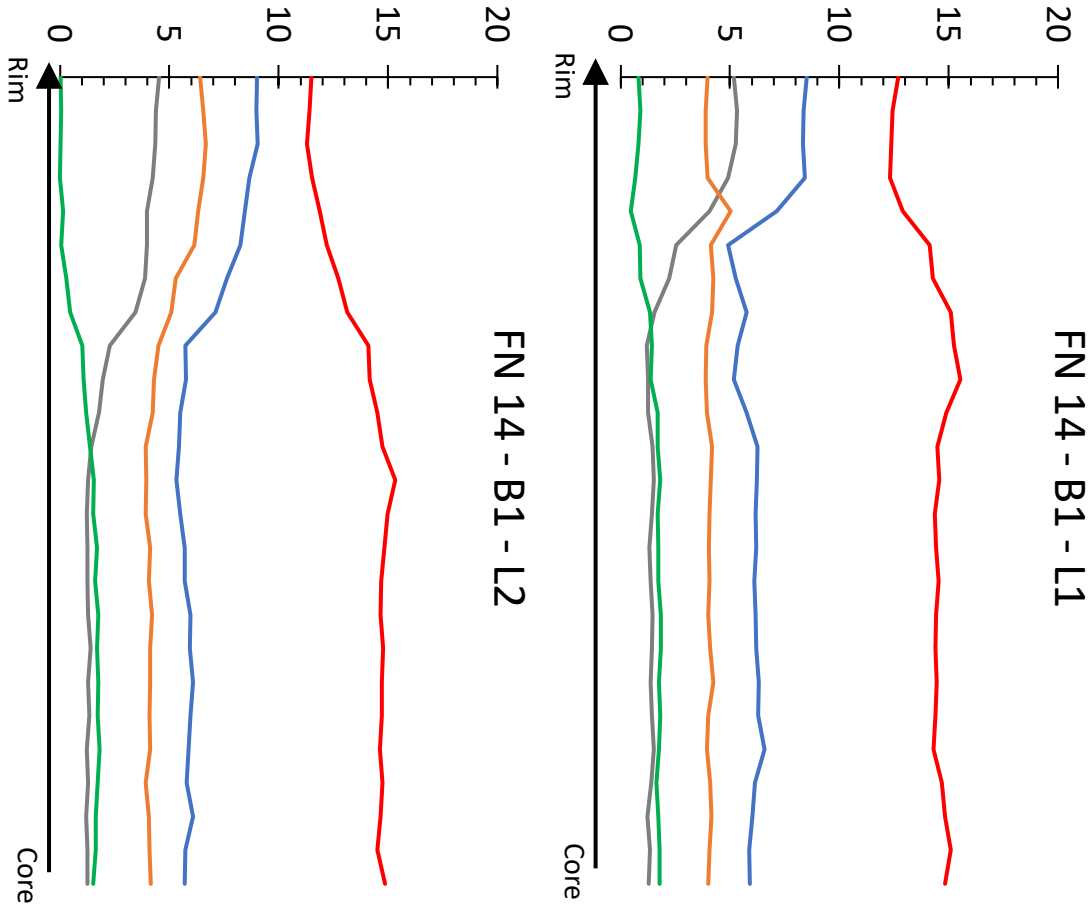
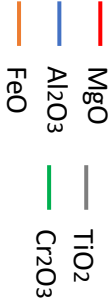
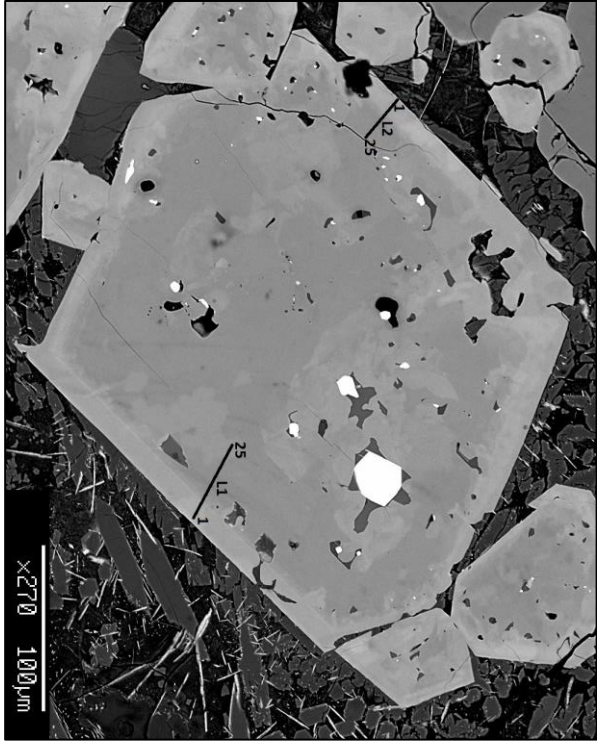
Sample	Sr88_ppm	Y89_ppm	Zr90_ppm	Nb93_ppm	Cs133_ppm	Ba137_ppm	La139_ppm	Ce140_ppm	Pr141_ppm
14-2-VTR-3	563	14	297	156.6	0.9	235.0	52.26	98.88	10.20
14-2-VTR-4	985	15	285	175.3	0.7	1197.2	50.53	98.11	9.92
14-2-VTR-5	756	17	303	184.1	0.2	1753.5	64.57	128.43	12.52
14-3-VTR-1	433	11	85	88.3	0.2	1325.9	34.88	73.49	7.93
18-1-VTR-1	409	14	319	185.9	1.6	1075.2	59.72	101.05	9.59
18-1-VTR-2	569	11	265	169.2	2.4	881.4	51.54	84.41	7.86
18-1-VTR-3	422	12	306	196.1	2.2	704.1	52.37	86.21	7.61
18-2-VTR-1	416	15	363	200.7	2.3	792.1	57.40	98.66	9.26
18-2-VTR-2	432	15	347	195.2	2.2	1002.4	62.87	108.97	9.97
18-2-VTR-3	616	11	222	152.2	1.2	658.4	61.10	113.58	11.33
30-1-VTR-1	61	19	415	204.6	1.7	383.8	58.50	104.53	10.03
30-1-VTR-2	59	17	422	211.2	1.9	384.4	53.63	95.45	8.93
30-1-VTR-3	30	18	421	206.2	2.0	221.6	55.85	99.39	9.68
30-1-VTR-4	90	17	423	217.7	1.8	557.1	57.77	101.31	9.67
30-3-VTR-1	121	21	445	224.3	1.7	614.9	63.74	114.97	11.48
30-3-VTR-2	119	21	472	230.8	1.9	613.4	63.59	114.41	11.27
30-3-VTR-3	83	20	462	225.6	2.0	426.4	60.83	112.07	10.91
38-1-VTR-1	190	16	372	201.9	1.9	776.3	55.05	97.91	9.38
38-1-VTR-2	477	23	511	261.0	0.9	2119.2	71.78	128.87	13.10
38-1-VTR-3	136	17	406	214.1	2.2	711.6	55.34	97.96	9.57
38-1-VTR-4	264	17	385	196.5	2.3	905.4	54.59	97.88	9.89
38-2-VTR-1	479	19	379	192.4	2.1	1046.1	63.91	116.97	11.90
38-2-VTR-2	427	19	387	194.2	2.1	1008.6	58.30	110.24	11.31
38-2-VTR-3	415	18	377	188.8	2.0	942.7	56.18	104.75	10.79
38-2-VTR-4	519	18	363	183.0	1.5	888.2	56.09	102.81	10.41
38-3-VTR-1	155	18	424	214.5	2.4	680.7	56.33	99.95	9.78
38-3-VTR-2	925	26	625	277.9	0.2	1396.5	72.57	136.67	13.82
38-3-VTR-3	193	18	434	222.7	2.6	669.4	56.41	98.31	9.63
38-4-VTR-1	555	14	336	202.9	2.1	1211.9	54.30	95.59	8.84
38-4-VTR-2	640	15	328	181.3	2.1	1199.5	49.35	93.59	9.11
38-4-VTR-3	532	14	338	190.2	2.1	1022.8	48.19	87.03	8.60
38-5-VTR-1	326	12	305	177.1	1.7	845.3	42.43	76.23	7.27
38-5-VTR-2	337	12	299	179.8	1.6	790.0	45.37	83.03	8.09
38-5-VTR-3	313	9	244	155.0	1.5	632.2	33.97	62.09	5.87
41-2-VTR-1	293	32	432	211.3	<LOD	340.5	65.72	109.52	9.68
41-2-VTR-2	485	18	139	46.7	<LOD	340.8	27.82	62.22	7.54
41-2-VTR-3	348	34	208	49.7	<LOD	271.5	27.12	68.08	9.46
41-3-VTR-1	129	32	1496	871.3	3.0	133.0	76.07	183.87	19.25
41-3-VTR-2	259	31	1374	756.0	1.5	350.4	82.90	186.69	19.84

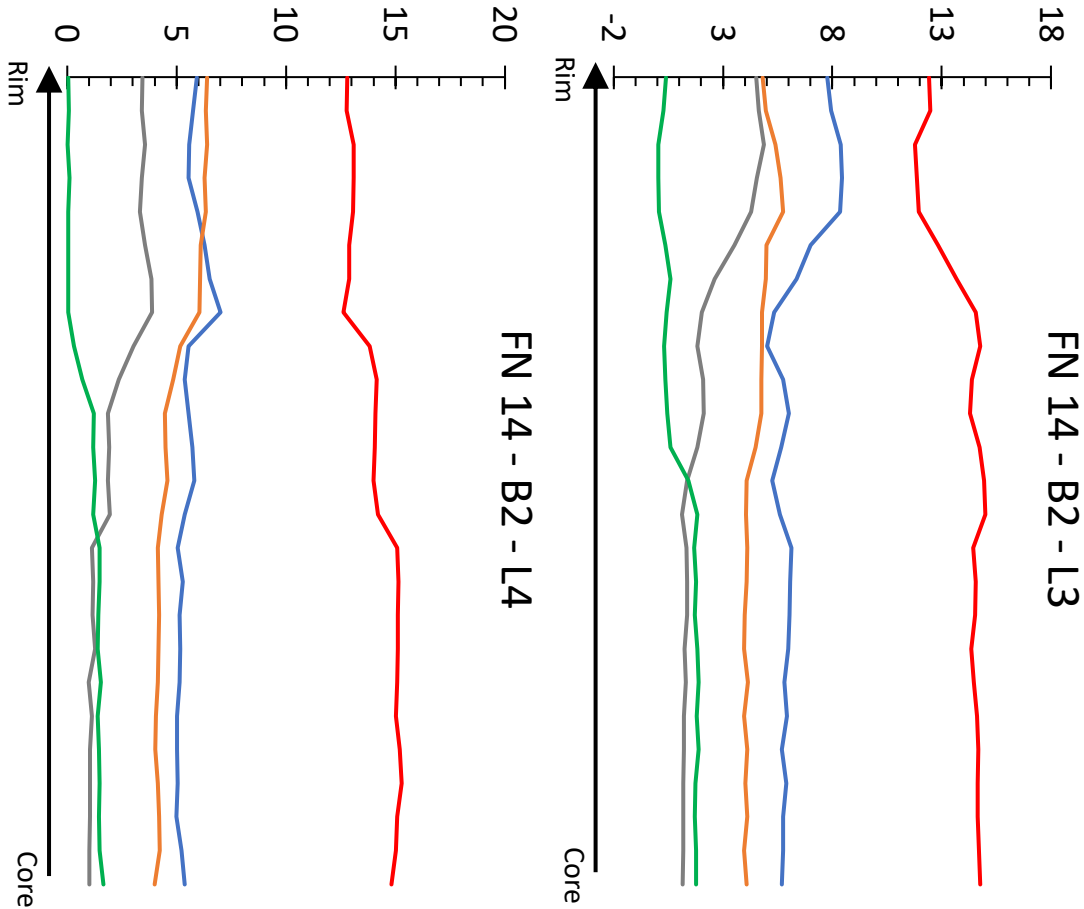
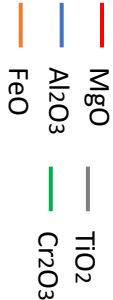
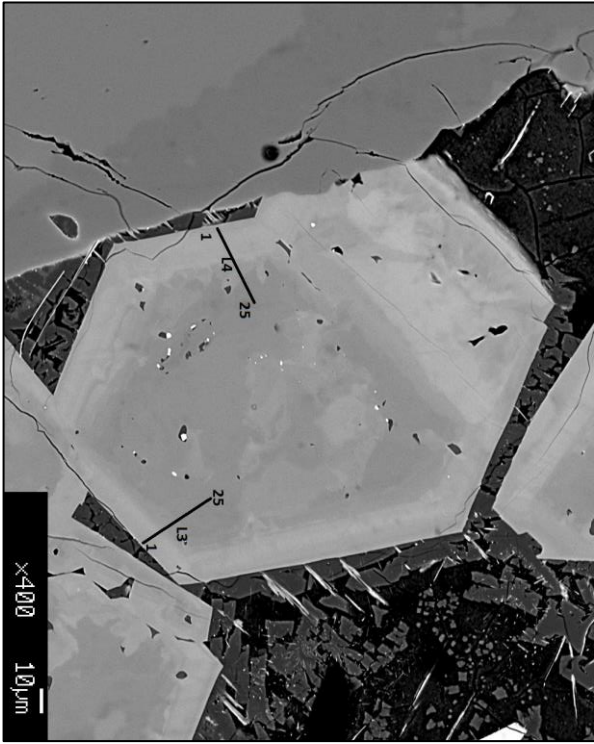
Sample	Nd146_ppm	Sm147_ppm	Eu153_ppm	Gd157_ppm	Tb159_ppm	Dy163_ppm	Ho165_ppm	Er166_ppm
14-2-VTR-3	33.78	5.07	1.65	3.97	0.52	2.75	0.53	1.28
14-2-VTR-4	32.47	5.53	1.46	3.93	0.51	3.05	0.52	1.46
14-2-VTR-5	42.25	6.39	1.78	4.95	0.63	3.34	0.61	1.65
14-3-VTR-1	26.07	4.05	0.72	3.31	0.39	2.21	0.38	0.98
18-1-VTR-1	29.78	4.93	1.58	3.81	0.50	2.64	0.51	1.37
18-1-VTR-2	24.39	3.49	0.67	2.44	0.36	2.13	0.33	0.86
18-1-VTR-3	22.63	2.94	0.62	2.74	0.33	2.04	0.37	1.16
18-2-VTR-1	29.49	4.89	0.96	3.34	0.48	2.85	0.51	1.37
18-2-VTR-2	31.34	4.98	1.20	3.57	0.59	3.13	0.53	1.45
18-2-VTR-3	42.10	6.04	2.70	4.00	0.42	2.87	0.40	1.15
30-1-VTR-1	33.15	5.22	1.06	4.51	0.67	3.62	0.72	1.80
30-1-VTR-2	30.02	5.05	1.00	3.76	0.58	3.20	0.55	1.85
30-1-VTR-3	31.67	4.75	0.89	4.27	0.62	3.63	0.64	1.90
30-1-VTR-4	31.94	4.73	0.96	4.00	0.54	3.38	0.62	1.82
30-3-VTR-1	37.44	6.02	1.49	4.74	0.69	4.44	0.83	1.95
30-3-VTR-2	38.35	6.21	1.43	5.29	0.71	3.92	0.77	2.08
30-3-VTR-3	34.82	5.97	1.14	4.97	0.74	3.86	0.67	1.96
38-1-VTR-1	31.13	5.53	0.97	3.89	0.58	3.15	0.65	1.52
38-1-VTR-2	44.15	7.43	1.91	5.61	0.82	4.48	0.83	2.17
38-1-VTR-3	30.69	5.23	1.23	4.32	0.56	3.28	0.60	1.71
38-1-VTR-4	32.26	5.38	1.17	4.23	0.60	3.39	0.62	1.69
38-2-VTR-1	40.69	6.50	1.74	5.61	0.73	4.05	0.72	1.93
38-2-VTR-2	37.75	6.54	1.65	4.73	0.74	3.92	0.68	1.95
38-2-VTR-3	36.89	6.42	1.66	4.76	0.68	3.78	0.64	1.51
38-2-VTR-4	36.62	6.09	1.27	4.84	0.71	3.47	0.62	1.43
38-3-VTR-1	33.56	5.52	1.27	4.33	0.65	3.43	0.67	1.76
38-3-VTR-2	46.66	7.38	2.38	6.04	0.95	5.47	0.96	2.64
38-3-VTR-3	31.22	5.27	1.13	4.31	0.58	3.51	0.65	1.84
38-4-VTR-1	28.53	4.13	1.12	3.22	0.45	2.85	0.46	1.32
38-4-VTR-2	30.20	4.65	1.49	4.16	0.52	3.05	0.53	1.31
38-4-VTR-3	29.46	4.38	1.25	3.64	0.49	2.48	0.43	1.23
38-5-VTR-1	23.50	3.93	0.90	3.67	0.43	2.21	0.51	1.35
38-5-VTR-2	25.51	4.36	1.09	3.00	0.42	2.47	0.48	1.25
38-5-VTR-3	18.31	2.84	0.72	2.96	0.38	1.73	0.30	0.85
41-2-VTR-1	30.15	6.76	1.51	6.62	1.03	6.51	1.23	3.87
41-2-VTR-2	29.85	5.55	2.05	4.62	0.61	3.50	0.62	1.63
41-2-VTR-3	38.62	10.23	2.13	9.82	1.29	7.78	1.41	3.34
41-3-VTR-1	61.70	10.58	0.82	8.10	1.23	6.60	1.34	3.67
41-3-VTR-2	62.03	11.11	1.15	7.89	1.20	6.69	1.25	3.38

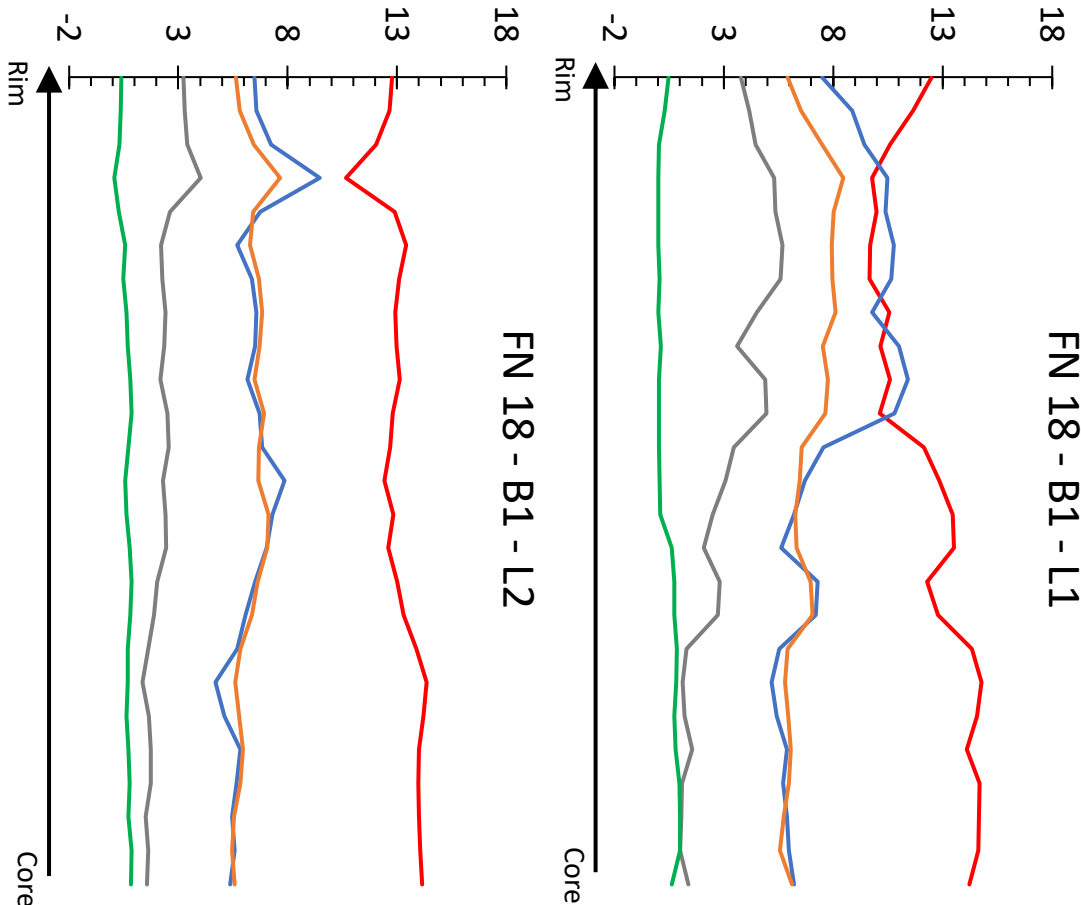
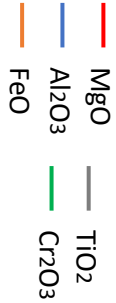
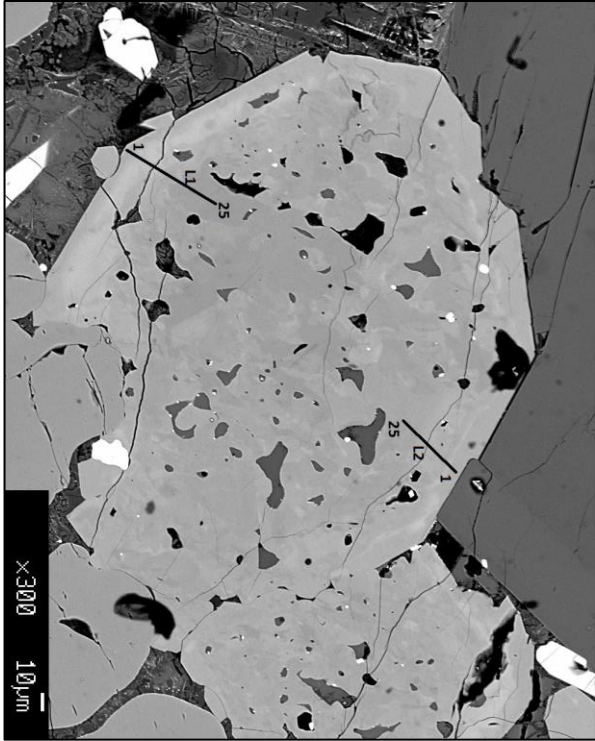
Sample	Tm169_ppm	Yb173_ppm	Lu175_ppm	Hf178_ppm	Ta181_ppm	Pb208_ppm	Th232_ppm	U238_ppm
14-2-VTR-3	0.14	1.08	0.14	4.46	8.30	5.10	8.69	3.66
14-2-VTR-4	0.17	1.04	0.16	4.24	8.83	7.50	10.69	4.13
14-2-VTR-5	0.20	1.38	0.13	4.33	9.17	10.41	10.76	5.02
14-3-VTR-1	0.13	0.59	0.08	1.18	3.73	3.28	3.85	1.12
18-1-VTR-1	0.15	1.07	0.14	4.83	8.66	5.32	14.42	6.15
18-1-VTR-2	0.14	0.82	0.09	3.27	7.41	5.69	12.33	5.49
18-1-VTR-3	0.11	0.83	0.08	3.80	8.98	5.10	15.00	6.55
18-2-VTR-1	0.20	1.30	0.13	4.76	9.45	7.55	15.61	6.79
18-2-VTR-2	0.18	1.25	0.15	4.77	9.74	6.65	15.66	6.87
18-2-VTR-3	0.17	0.33	0.07	3.18	6.37	4.32	9.91	4.36
30-1-VTR-1	0.26	1.85	0.20	7.02	9.81	7.82	17.10	6.39
30-1-VTR-2	0.21	1.53	0.17	7.33	10.29	7.79	17.77	6.58
30-1-VTR-3	0.24	1.59	0.18	6.75	10.32	7.91	17.45	6.26
30-1-VTR-4	0.23	1.62	0.18	6.53	10.53	8.13	17.37	6.54
30-3-VTR-1	0.29	1.80	0.26	6.93	11.08	8.41	18.61	7.21
30-3-VTR-2	0.26	1.73	0.25	7.62	11.10	8.03	19.25	7.30
30-3-VTR-3	0.31	1.82	0.21	7.32	10.77	8.36	19.12	7.21
38-1-VTR-1	0.18	1.15	0.16	5.94	11.11	7.34	13.86	6.08
38-1-VTR-2	0.31	1.81	0.24	8.34	14.10	10.41	18.35	7.44
38-1-VTR-3	0.23	1.43	0.18	6.45	11.37	6.56	15.72	6.48
38-1-VTR-4	0.24	1.46	0.18	6.41	10.17	8.31	14.37	5.85
38-2-VTR-1	0.26	1.29	0.15	6.45	10.63	7.70	12.27	5.06
38-2-VTR-2	0.23	1.29	0.18	6.89	10.69	7.44	11.70	4.75
38-2-VTR-3	0.22	1.31	0.17	6.63	10.55	7.15	11.40	4.74
38-2-VTR-4	0.23	1.14	0.18	6.65	10.53	7.34	10.52	4.22
38-3-VTR-1	0.26	1.40	0.20	6.91	11.65	7.25	17.39	7.30
38-3-VTR-2	0.35	1.91	0.26	9.60	14.49	6.17	24.84	9.85
38-3-VTR-3	0.26	1.52	0.18	6.94	11.99	8.93	17.95	7.66
38-4-VTR-1	0.17	1.22	0.12	5.46	10.86	7.11	12.04	4.89
38-4-VTR-2	0.17	1.11	0.15	5.54	10.05	7.60	9.72	3.42
38-4-VTR-3	0.15	0.77	0.12	5.57	10.15	7.65	9.43	3.49
38-5-VTR-1	0.19	0.89	0.10	4.54	8.46	7.50	10.14	3.97
38-5-VTR-2	0.11	0.73	0.10	4.35	8.30	7.83	10.34	3.98
38-5-VTR-3	0.08	0.49	0.07	3.85	6.97	7.05	8.40	3.33
41-2-VTR-1	0.61	3.39	0.44	6.55	11.26	2.56	12.30	11.70
41-2-VTR-2	0.16	1.50	0.17	3.04	3.43	2.87	0.58	0.11
41-2-VTR-3	0.45	2.50	0.29	4.81	3.12	2.07	1.14	0.23
41-3-VTR-1	0.46	3.24	0.40	21.65	38.91	15.99	51.22	19.46
41-3-VTR-2	0.44	3.11	0.36	22.15	38.75	13.82	55.96	14.37

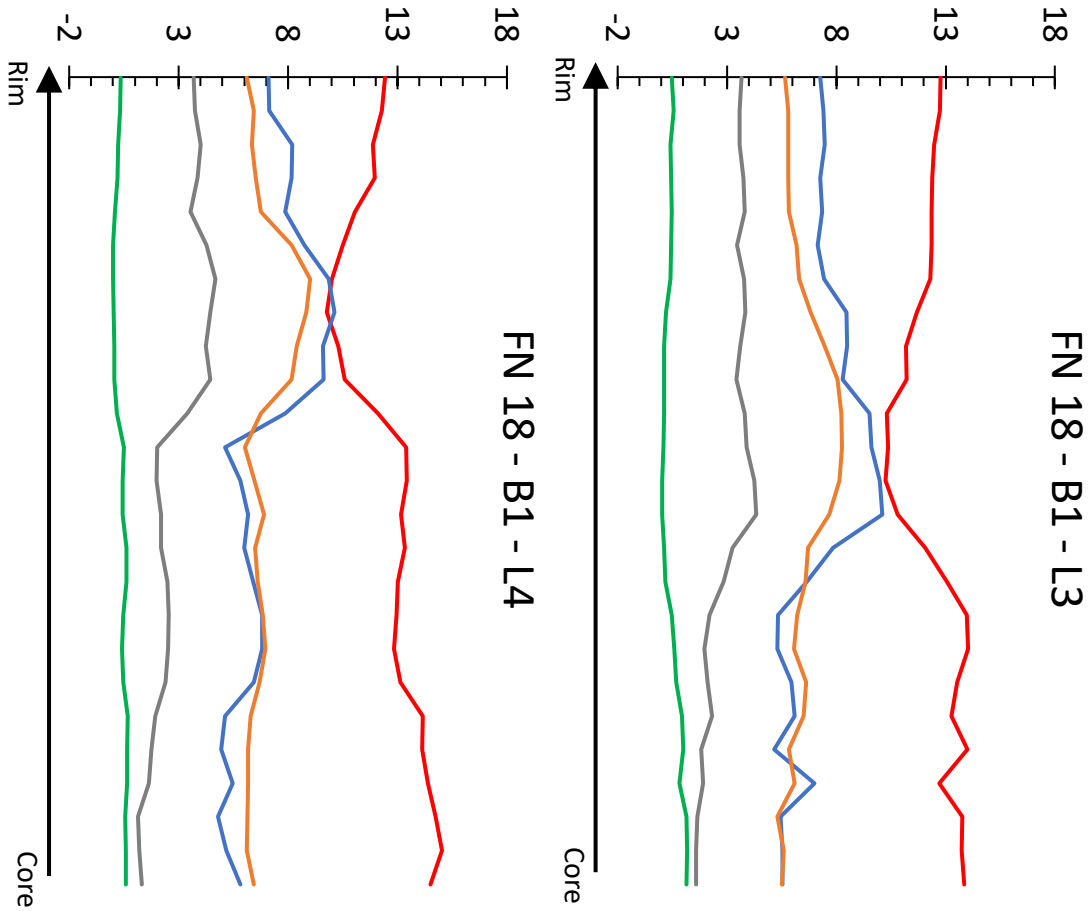
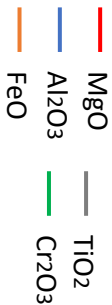
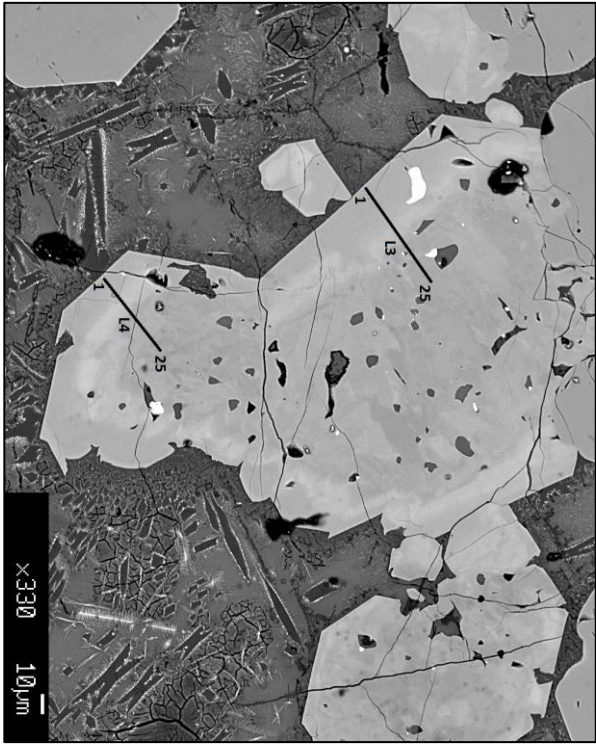












Spot Analyses	Na2O	SiO2	TiO2	MnO	K2O	MgO	P2O5	Cr2O3	FeO	CaO	Al2O3	Total
Line 1 FN14-A-1-L1	0.89	42.04	5.23	0.12	0.02	11.32	0.20	0.19	5.82	21.95	9.61	97.38
Line 2 FN14-A-1-L1	0.93	42.27	5.41	0.07	0.02	11.46	0.16	0.17	5.45	21.87	9.47	97.27
Line 3 FN14-A-1-L1	0.92	41.82	5.40	0.09	0.03	11.16	0.18	0.03	6.25	21.67	9.83	97.37
Line 4 FN14-A-1-L1	0.86	41.95	5.26	0.14	0.02	11.05	0.17	0.00	6.49	21.65	9.68	97.28
Line 5 FN14-A-1-L1	0.78	42.14	5.17	0.10	0.00	11.26	0.18	0.10	6.47	21.94	9.41	97.55
Line 6 FN14-A-1-L1	0.72	42.42	4.95	0.07	0.01	11.43	0.14	0.12	6.36	22.07	9.12	97.42
Line 7 FN14-A-1-L1	0.72	43.21	4.71	0.10	0.01	11.67	0.21	0.12	5.88	22.14	8.86	97.62
Line 8 FN14-A-1-L1	0.65	45.61	3.90	0.08	0.01	13.12	0.16	0.06	5.50	22.45	6.59	98.14
Line 9 FN14-A-1-L1	0.58	46.64	3.18	0.07	0.03	13.83	0.23	0.06	4.73	22.40	5.79	97.54
Line 10 FN14-A-1-L1	0.74	46.80	3.07	0.08	0.01	13.84	0.18	0.26	4.63	22.37	5.68	97.66
Line 11 FN14-A-1-L1	0.67	47.58	2.32	0.09	0.00	14.16	0.17	0.67	4.17	22.20	5.37	97.40
Line 12 FN14-A-1-L1	0.90	48.26	2.01	0.13	0.00	14.36	0.16	1.18	4.01	21.50	5.47	97.99
Line 13 FN14-A-1-L1	0.88	48.24	1.80	0.10	0.00	14.42	0.14	1.18	4.08	21.36	5.74	97.94
Line 14 FN14-A-1-L1	0.91	48.19	1.89	0.09	0.00	14.31	0.13	1.19	4.24	21.24	5.83	98.02
Line 15 FN14-A-1-L1	1.00	49.06	1.58	0.07	0.01	14.80	0.17	1.13	4.09	20.89	5.52	98.31
Line 16 FN14-A-1-L1	1.04	50.15	1.19	0.07	0.01	15.49	0.13	1.11	4.03	20.15	4.98	98.35
Line 17 FN14-A-1-L1	1.06	50.03	1.21	0.07	0.01	15.63	0.10	1.27	3.94	19.91	4.85	98.08
Line 18 FN14-A-1-L1	1.24	49.69	1.35	0.05	0.01	15.05	0.13	1.55	3.88	19.75	5.72	98.42
Line 19 FN14-A-1-L1	1.40	49.06	1.31	0.05	0.01	14.58	0.10	1.58	3.86	19.63	6.37	97.95
Line 20 FN14-A-1-L1	1.27	49.14	1.50	0.06	0.01	14.62	0.16	1.52	3.91	19.80	6.33	98.32
Line 21 FN14-A-1-L1	1.39	49.44	1.37	0.06	0.00	14.49	0.09	1.53	3.85	19.58	6.26	98.06
Line 22 FN14-A-1-L1	1.31	49.38	1.35	0.09	0.00	14.67	0.13	1.63	3.71	19.66	6.38	98.31
Line 23 FN14-A-1-L1	1.29	49.59	1.47	0.08	0.00	14.86	0.15	1.50	3.82	19.56	6.41	98.74
Line 24 FN14-A-1-L1	1.47	49.03	1.51	0.06	0.00	14.66	0.08	1.54	3.85	19.67	6.37	98.25
Line 25 FN14-A-1-L1	1.32	49.19	1.48	0.09	0.00	14.61	0.16	1.68	3.79	19.63	6.26	98.21
Line 26 FN14-A-1-L1	1.38	49.42	1.37	0.07	0.00	14.80	0.13	1.51	3.95	19.52	6.17	98.32
Line 27 FN14-A-1-L1	1.45	49.50	1.35	0.07	0.00	15.04	0.13	1.45	3.92	19.56	5.99	98.46
Line 28 FN14-A-1-L1	1.34	49.85	1.33	0.09	0.00	15.11	0.09	1.44	3.87	19.54	5.86	98.52
Line 29 FN14-A-1-L1	1.30	50.48	1.27	0.09	0.00	15.07	0.13	1.57	4.11	19.65	6.03	99.70
Line 30 FN14-A-1-L1	1.36	50.08	1.25	0.11	0.01	15.12	0.11	1.47	4.05	19.76	6.01	99.33
Line 31 FN14-A-1-L1	1.32	50.14	1.29	0.12	0.00	15.27	0.16	1.43	4.14	19.72	5.98	99.57
Line 32 FN14-A-1-L1	1.38	50.42	1.23	0.14	0.00	15.02	0.18	1.52	4.01	19.74	6.04	99.67
Line 33 FN14-A-1-L1	1.38	49.97	1.32	0.13	0.00	15.17	0.12	1.40	3.97	19.73	6.03	99.22
Line 34 FN14-A-1-L1	1.27	50.06	1.29	0.09	0.03	15.09	0.14	1.46	4.19	19.56	6.04	99.22
Line 35 FN14-A-1-L1	1.47	50.29	1.32	0.11	0.00	15.31	0.14	1.48	4.20	19.90	5.89	100.11
Line 36 FN14-A-1-L1	1.29	50.26	1.27	0.11	0.00	15.29	0.12	1.46	4.04	19.61	5.69	99.13
Line 37 FN14-A-1-L1	1.31	50.48	1.23	0.12	0.01	15.27	0.11	1.32	3.99	19.89	5.73	99.46
Line 38 FN14-A-1-L1	1.19	50.31	1.22	0.11	0.01	15.34	0.16	1.44	4.11	19.75	5.65	99.30
Line 39 FN14-A-1-L1	1.33	50.49	1.32	0.08	0.00	15.17	0.16	1.34	4.04	19.80	5.65	99.39
Line 40 FN14-A-1-L1	1.32	50.34	1.21	0.10	0.01	15.11	0.09	1.34	3.99	19.75	5.72	98.99
Line 41 FN14-A-1-L1	1.37	50.43	1.31	0.02	0.00	15.27	0.14	1.52	3.90	19.82	5.89	99.67
Line 42 FN14-A-1-L1	1.27	50.07	1.27	0.04	0.01	15.15	0.13	1.42	4.01	19.75	5.89	99.01
Line 43 FN14-A-1-L1	1.36	49.90	1.35	0.12	0.00	15.24	0.12	1.42	4.05	19.77	5.77	99.09
Line 44 FN14-A-1-L1	1.38	50.15	1.26	0.07	0.00	15.08	0.14	1.45	4.14	19.97	5.82	99.46
Line 45 FN14-A-1-L1	1.30	50.28	1.35	0.11	0.01	15.09	0.07	1.37	4.10	20.02	5.77	99.48
Line 46 FN14-A-1-L1	1.27	50.44	1.28	0.08	0.01	15.13	0.12	1.35	4.04	19.98	5.86	99.57
Line 47 FN14-A-1-L1	1.40	50.19	1.19	0.10	0.00	15.02	0.17	1.49	4.05	19.83	5.66	99.09
Line 48 FN14-A-1-L1	1.28	50.13	1.25	0.07	0.00	15.20	0.14	1.44	3.95	19.94	5.88	99.28
Line 49 FN14-A-1-L1	1.29	50.21	1.23	0.09	0.01	14.85	0.08	1.44	3.99	19.91	5.92	99.03
Line 50 FN14-A-1-L1	1.37	50.22	1.25	0.09	0.00	15.01	0.13	1.50	4.00	20.03	5.71	99.31
Line 1 FN14-A-2-L2	0.96	44.03	5.46	0.16	0.02	11.79	0.15	0.31	5.35	22.31	9.31	99.84
Line 2 FN14-A-2-L2	0.84	43.08	5.37	0.14	0.03	11.13	0.17	0.06	6.18	21.88	9.69	98.57
Line 3 FN14-A-2-L2	0.98	43.35	5.28	0.14	0.01	11.33	0.21	0.01	6.55	22.25	9.66	99.76

Spot Analyses	Na2O	SiO2	TiO2	MnO	K2O	MgO	P2O5	Cr2O3	FeO	CaO	Al2O3	Total
Line 4 FN14-A-2-L2	0.85	43.71	5.26	0.11	0.02	11.42	0.15	0.09	6.20	22.22	9.37	99.40
Line 5 FN14-A-2-L2	0.84	44.15	4.83	0.13	0.00	11.74	0.15	0.10	5.85	22.46	9.06	99.30
Line 6 FN14-A-2-L2	0.80	44.31	4.86	0.12	0.00	12.03	0.21	0.13	5.79	22.47	8.84	99.57
Line 7 FN14-A-2-L2	0.62	45.59	4.04	0.13	0.03	12.93	0.12	0.24	5.11	22.65	7.59	99.05
Line 8 FN14-A-2-L2	0.67	46.69	3.61	0.05	0.01	13.34	0.16	0.35	5.06	22.79	7.00	99.73
Line 9 FN14-A-2-L2	0.90	45.86	4.05	0.07	0.02	12.68	0.14	0.42	4.98	22.51	7.75	99.38
Line 10 FN14-A-2-L2	0.78	45.65	4.29	0.14	0.02	12.48	0.21	0.37	4.87	22.59	7.98	99.37
Line 11 FN14-A-2-L2	0.76	46.89	3.61	0.09	0.02	13.46	0.21	0.56	4.66	22.58	7.00	99.84
Line 12 FN14-A-2-L2	1.13	48.53	2.22	0.03	0.01	14.05	0.14	1.24	4.39	21.26	6.49	99.49
Line 13 FN14-A-2-L2	1.25	50.07	1.47	0.02	0.01	14.39	0.13	1.43	4.17	20.26	6.03	99.23
Line 14 FN14-A-2-L2	1.28	50.00	1.46	0.13	0.00	14.66	0.13	1.51	4.27	20.09	6.06	99.59
Line 15 FN14-A-2-L2	1.25	50.34	1.35	0.14	0.00	14.90	0.13	1.57	4.25	20.06	6.04	100.04
Line 16 FN14-A-2-L2	1.32	50.32	1.29	0.06	0.01	14.83	0.10	1.57	4.13	20.01	6.25	99.89
Line 17 FN14-A-2-L2	1.33	50.45	1.24	0.09	0.01	14.70	0.16	1.59	4.11	20.09	6.05	99.83
Line 18 FN14-A-2-L2	1.36	50.69	1.18	0.10	0.01	14.79	0.12	1.51	4.05	20.05	6.23	100.10
Line 19 FN14-A-2-L2	1.48	50.31	1.20	0.08	0.00	14.80	0.14	1.59	4.07	19.96	5.93	99.57
Line 20 FN14-A-2-L2	1.51	50.57	1.24	0.10	0.00	14.82	0.11	1.72	4.14	19.87	5.94	100.02
Line 21 FN14-A-2-L2	1.46	50.49	1.17	0.03	0.00	15.02	0.14	1.66	4.17	19.78	5.92	99.83
Line 22 FN14-A-2-L2	1.43	50.64	1.22	0.12	0.02	14.78	0.10	1.64	4.34	19.64	6.19	100.12
Line 23 FN14-A-2-L2	1.41	50.57	1.23	0.00	0.01	14.78	0.10	1.61	4.16	19.51	6.34	99.72
Line 24 FN14-A-2-L2	1.45	50.14	1.21	0.11	0.01	14.66	0.17	1.57	4.21	19.41	6.32	99.26
Line 25 FN14-A-2-L2	1.54	50.03	1.22	0.10	0.02	14.56	0.16	1.65	4.31	19.29	6.35	99.22
Line 1 FN14-A-2-L3	0.85	44.82	4.90	0.08	0.01	12.71	0.09	0.89	3.98	22.64	8.17	99.14
Line 2 FN14-A-2-L3	0.90	46.10	4.56	0.09	0.00	12.66	0.15	0.30	5.43	22.58	7.31	100.07
Line 3 FN14-A-2-L3	0.82	45.99	4.35	0.13	0.00	12.58	0.14	0.05	6.26	22.32	7.02	99.67
Line 4 FN14-A-2-L3	0.70	45.99	4.53	0.14	0.00	12.67	0.18	0.05	6.22	22.27	6.89	99.64
Line 5 FN14-A-2-L3	0.67	46.12	4.21	0.14	0.00	12.51	0.14	0.06	6.16	22.54	6.73	99.27
Line 6 FN14-A-2-L3	0.60	46.08	4.13	0.11	0.02	12.70	0.13	0.07	6.31	22.57	6.77	99.49
Line 7 FN14-A-2-L3	0.81	41.95	5.96	0.13	0.00	10.95	0.13	0.11	6.66	22.38	9.97	99.06
Line 8 FN14-A-2-L3	0.70	42.75	5.65	0.12	0.01	11.71	0.17	0.05	6.54	22.33	9.42	99.45
Line 9 FN14-A-2-L3	0.68	44.00	4.96	0.11	0.01	11.78	0.10	0.03	6.60	22.40	8.65	99.32
Line 10 FN14-A-2-L3	0.65	45.69	4.18	0.11	0.01	12.60	0.16	0.02	6.19	22.51	7.09	99.22
Line 11 FN14-A-2-L3	0.66	45.86	4.11	0.11	0.00	12.51	0.19	0.05	5.99	22.58	7.18	99.24
Line 12 FN14-A-2-L3	0.68	45.31	4.32	0.10	0.01	12.57	0.18	0.14	5.77	22.86	7.74	99.69
Line 13 FN14-A-2-L3	0.57	45.12	4.59	0.07	0.01	12.59	0.18	0.03	5.69	23.00	7.62	99.47
Line 14 FN14-A-2-L3	0.66	43.80	5.18	0.06	0.02	11.98	0.17	0.15	5.60	22.69	9.09	99.40
Line 15 FN14-A-2-L3	0.66	46.37	3.86	0.08	0.00	12.97	0.16	0.24	5.08	22.85	7.39	99.65
Line 16 FN14-A-2-L3	0.78	49.00	2.34	0.13	0.01	14.17	0.17	1.18	4.63	22.07	5.88	100.36
Line 17 FN14-A-2-L3	0.93	49.27	1.85	0.09	0.00	14.47	0.14	1.42	4.31	21.30	5.96	99.74
Line 18 FN14-A-2-L3	0.98	49.97	1.70	0.09	0.03	14.80	0.09	1.13	4.44	20.39	5.79	99.41
Line 19 FN14-A-2-L3	0.96	50.03	1.09	0.12	0.04	15.88	0.10	1.01	4.89	18.50	5.79	98.42
Line 20 FN14-A-2-L3	1.19	49.34	1.10	0.09	0.04	15.54	0.11	1.33	4.65	18.33	6.15	97.87
Line 21 FN14-A-2-L3	1.33	50.60	1.15	0.12	0.00	15.37	0.14	1.42	4.19	19.93	5.60	99.84
Line 22 FN14-A-2-L3	1.34	50.52	1.26	0.06	0.00	14.65	0.08	1.42	4.30	19.95	5.80	99.38
Line 23 FN14-A-2-L3	1.44	50.25	1.26	0.08	0.01	14.85	0.14	1.72	4.11	19.97	6.01	99.84
Line 24 FN14-A-2-L3	1.40	50.37	1.27	0.08	0.00	14.80	0.15	1.52	4.27	19.88	5.96	99.71
Line 25 FN14-A-2-L3	1.45	50.22	1.27	0.07	0.00	14.72	0.11	1.50	4.23	19.99	5.96	99.52
Line 1 FN14-B-1-L1	1.04	44.59	5.18	0.06	0.01	12.70	0.17	0.82	3.97	22.26	8.52	99.32
Line 2 FN14-B-1-L1	0.92	44.72	5.33	0.05	0.02	12.43	0.14	0.91	3.88	22.48	8.37	99.24
Line 3 FN14-B-1-L1	1.02	44.37	5.25	0.05	0.01	12.36	0.16	0.81	3.89	22.44	8.34	98.70
Line 4 FN14-B-1-L1	0.81	44.44	4.91	0.12	0.00	12.32	0.14	0.68	3.99	22.26	8.43	98.10
Line 5 FN14-B-1-L1	0.71	45.23	4.05	0.06	0.01	12.89	0.17	0.47	5.02	22.28	7.15	98.04
Line 6 FN14-B-1-L1	0.51	48.25	2.53	0.13	0.00	14.12	0.16	0.89	4.13	22.58	4.91	98.20

Spot Analyses	Na2O	SiO2	TiO2	MnO	K2O	MgO	P2O5	Cr2O3	FeO	CaO	Al2O3	Total
Line 7 FN14-B-1-L1	0.80	48.78	2.23	0.09	0.01	14.28	0.17	0.91	4.25	21.71	5.26	98.48
Line 8 FN14-B-1-L1	1.12	49.91	1.54	0.08	0.00	15.09	0.16	1.35	4.17	20.27	5.75	99.44
Line 9 FN14-B-1-L1	1.15	50.02	1.20	0.12	0.00	15.23	0.14	1.44	3.92	20.13	5.35	98.70
Line 10 FN14-B-1-L1	1.14	50.45	1.27	0.10	0.01	15.52	0.09	1.37	3.90	20.04	5.19	99.07
Line 11 FN14-B-1-L1	1.27	49.36	1.26	0.05	0.01	14.89	0.12	1.68	3.95	19.42	5.76	97.77
Line 12 FN14-B-1-L1	1.43	49.17	1.45	0.03	0.00	14.47	0.10	1.68	4.18	19.47	6.26	98.24
Line 13 FN14-B-1-L1	1.36	49.41	1.51	0.08	0.00	14.58	0.13	1.82	4.11	19.59	6.22	98.82
Line 14 FN14-B-1-L1	1.45	48.97	1.43	0.12	0.01	14.36	0.10	1.68	4.05	19.40	6.18	97.75
Line 15 FN14-B-1-L1	1.29	49.28	1.31	0.11	0.01	14.41	0.13	1.73	4.04	19.74	6.20	98.25
Line 16 FN14-B-1-L1	1.36	49.39	1.36	0.06	0.00	14.55	0.13	1.71	4.05	19.50	6.12	98.24
Line 17 FN14-B-1-L1	1.38	49.18	1.47	0.06	0.00	14.42	0.16	1.83	4.02	19.73	6.16	98.41
Line 18 FN14-B-1-L1	1.33	48.99	1.42	0.03	0.00	14.40	0.12	1.85	4.09	19.55	6.21	97.99
Line 19 FN14-B-1-L1	1.48	49.64	1.39	0.08	0.00	14.45	0.11	1.76	4.24	19.52	6.31	98.98
Line 20 FN14-B-1-L1	1.44	49.31	1.42	0.06	0.02	14.38	0.17	1.82	4.01	19.63	6.29	98.55
Line 21 FN14-B-1-L1	1.55	49.39	1.52	0.10	0.01	14.29	0.14	1.75	3.95	19.29	6.58	98.57
Line 22 FN14-B-1-L1	1.47	49.84	1.39	0.07	0.01	14.69	0.12	1.63	4.09	19.74	6.15	99.20
Line 23 FN14-B-1-L1	1.39	49.94	1.23	0.09	0.00	14.84	0.11	1.72	4.15	19.94	6.01	99.43
Line 24 FN14-B-1-L1	1.46	50.28	1.34	0.05	0.00	15.09	0.15	1.77	4.07	19.86	5.87	99.94
Line 25 FN14-B-1-L1	1.42	49.93	1.28	0.07	0.01	14.82	0.10	1.77	4.00	19.78	5.90	99.08
Line 1 FN14-B-1-L2	0.86	43.20	4.53	0.10	0.01	11.49	0.20	0.02	6.41	21.99	9.00	97.81
Line 2 FN14-B-1-L2	0.88	43.24	4.40	0.16	0.00	11.40	0.20	0.05	6.56	22.06	8.99	97.93
Line 3 FN14-B-1-L2	0.79	43.60	4.35	0.14	0.01	11.29	0.17	0.04	6.66	21.79	9.05	97.90
Line 4 FN14-B-1-L2	0.78	43.64	4.24	0.08	0.01	11.53	0.17	0.00	6.54	21.76	8.66	97.40
Line 5 FN14-B-1-L2	0.77	44.26	3.97	0.13	0.01	11.87	0.22	0.15	6.32	22.00	8.46	98.16
Line 6 FN14-B-1-L2	0.73	44.79	3.98	0.15	0.01	12.19	0.13	0.06	6.14	21.96	8.26	98.41
Line 7 FN14-B-1-L2	0.67	45.28	3.88	0.16	0.00	12.73	0.20	0.30	5.28	22.11	7.62	98.23
Line 8 FN14-B-1-L2	0.69	45.80	3.45	0.05	0.00	13.12	0.16	0.46	5.08	22.32	7.12	98.24
Line 9 FN14-B-1-L2	0.64	47.69	2.29	0.00	0.00	14.11	0.11	1.01	4.50	22.18	5.74	98.28
Line 10 FN14-B-1-L2	0.84	48.42	1.95	0.09	0.02	14.17	0.20	1.08	4.30	21.51	5.77	98.35
Line 11 FN14-B-1-L2	0.89	48.74	1.79	0.08	0.00	14.50	0.19	1.21	4.24	21.40	5.50	98.55
Line 12 FN14-B-1-L2	1.11	49.00	1.43	0.07	0.00	14.75	0.14	1.38	3.91	20.69	5.44	97.91
Line 13 FN14-B-1-L2	1.13	49.83	1.29	0.09	0.00	15.32	0.13	1.56	3.94	20.08	5.33	98.70
Line 14 FN14-B-1-L2	1.21	49.96	1.22	0.11	0.00	14.97	0.12	1.52	3.92	19.86	5.49	98.38
Line 15 FN14-B-1-L2	1.30	49.70	1.25	0.07	0.00	14.83	0.17	1.69	4.11	19.76	5.69	98.58
Line 16 FN14-B-1-L2	1.33	49.43	1.27	0.12	0.01	14.67	0.17	1.60	4.06	19.87	5.70	98.23
Line 17 FN14-B-1-L2	1.45	49.39	1.30	0.03	0.00	14.66	0.14	1.75	4.22	19.61	5.96	98.50
Line 18 FN14-B-1-L2	1.30	49.59	1.40	0.10	0.01	14.78	0.13	1.70	4.12	19.84	5.94	98.91
Line 19 FN14-B-1-L2	1.40	49.60	1.29	0.11	0.02	14.71	0.16	1.75	4.11	19.56	6.07	98.78
Line 20 FN14-B-1-L2	1.39	49.29	1.36	0.09	0.00	14.72	0.11	1.72	4.08	19.60	5.98	98.34
Line 21 FN14-B-1-L2	1.34	49.16	1.23	0.07	0.01	14.62	0.13	1.82	4.13	19.63	5.87	98.01
Line 22 FN14-B-1-L2	1.35	49.49	1.28	0.08	0.01	14.75	0.13	1.71	3.91	19.79	5.78	98.28
Line 23 FN14-B-1-L2	1.29	49.80	1.20	0.11	0.01	14.64	0.13	1.63	4.06	19.83	6.07	98.76
Line 24 FN14-B-1-L2	1.27	49.81	1.27	0.11	0.01	14.51	0.11	1.64	4.10	19.70	5.73	98.25
Line 25 FN14-B-1-L2	1.31	49.73	1.27	0.10	0.00	14.86	0.11	1.52	4.15	19.79	5.69	98.54
Line 1 FN14-B-2-L3	0.96	45.31	4.53	0.06	0.00	12.42	0.18	0.41	4.81	22.15	7.77	98.60
Line 2 FN14-B-2-L3	0.96	44.93	4.63	0.08	0.01	12.49	0.14	0.28	4.96	22.34	7.95	98.77
Line 3 FN14-B-2-L3	0.86	44.29	4.88	0.06	0.01	11.76	0.20	0.04	5.41	21.91	8.38	97.80
Line 4 FN14-B-2-L3	0.77	44.53	4.56	0.11	0.01	11.86	0.16	0.06	5.64	22.22	8.43	98.35
Line 5 FN14-B-2-L3	0.88	44.14	4.29	0.11	0.00	11.95	0.15	0.07	5.74	22.35	8.36	98.04
Line 6 FN14-B-2-L3	0.75	46.01	3.52	0.07	0.02	12.82	0.17	0.35	4.98	22.40	7.01	98.11
Line 7 FN14-B-2-L3	0.77	47.40	2.61	0.01	0.01	13.69	0.14	0.59	4.96	22.15	6.37	98.71
Line 8 FN14-B-2-L3	0.87	48.63	2.02	0.10	0.01	14.55	0.11	0.41	4.79	21.58	5.33	98.39
Line 9 FN14-B-2-L3	0.86	49.05	1.82	0.11	0.00	14.76	0.11	0.30	4.77	21.46	5.03	98.27

Spot Analyses	Na2O	SiO2	TiO2	MnO	K2O	MgO	P2O5	Cr2O3	FeO	CaO	Al2O3	Total
Line 10 FN14-B-2-L3	0.87	48.87	2.09	0.12	0.00	14.37	0.14	0.37	4.76	21.38	5.76	98.73
Line 11 FN14-B-2-L3	0.91	48.75	2.11	0.07	0.00	14.29	0.13	0.46	4.74	21.37	6.01	98.84
Line 12 FN14-B-2-L3	0.96	49.13	1.83	0.12	0.00	14.73	0.19	0.60	4.50	21.13	5.67	98.86
Line 13 FN14-B-2-L3	1.18	50.02	1.35	0.09	0.00	14.94	0.11	1.42	4.08	20.02	5.24	98.45
Line 14 FN14-B-2-L3	1.32	49.69	1.13	0.09	0.01	14.98	0.12	1.83	4.04	19.62	5.60	98.43
Line 15 FN14-B-2-L3	1.38	49.48	1.32	0.11	0.01	14.45	0.17	1.68	4.10	19.48	6.12	98.30
Line 16 FN14-B-2-L3	1.30	49.77	1.35	0.06	0.01	14.55	0.14	1.78	4.09	19.72	6.07	98.84
Line 17 FN14-B-2-L3	1.41	49.56	1.36	0.07	0.01	14.53	0.13	1.72	3.98	19.71	6.05	98.53
Line 18 FN14-B-2-L3	1.38	49.25	1.23	0.09	0.01	14.36	0.09	1.82	3.95	19.82	5.99	97.98
Line 19 FN14-B-2-L3	1.36	49.34	1.30	0.05	0.00	14.47	0.08	1.88	4.14	19.59	5.81	98.02
Line 20 FN14-B-2-L3	1.38	49.69	1.23	0.07	0.00	14.61	0.13	1.81	3.97	19.67	5.91	98.47
Line 21 FN14-B-2-L3	1.41	49.88	1.22	0.02	0.00	14.67	0.14	1.89	4.10	19.78	5.68	98.79
Line 22 FN14-B-2-L3	1.38	49.59	1.18	0.10	0.02	14.63	0.14	1.73	4.02	19.61	5.89	98.28
Line 23 FN14-B-2-L3	1.37	50.25	1.19	0.10	0.00	14.64	0.13	1.71	4.12	19.70	5.76	98.98
Line 24 FN14-B-2-L3	1.35	50.12	1.18	0.08	0.01	14.69	0.09	1.78	3.97	19.55	5.75	98.56
Line 25 FN14-B-2-L3	1.42	50.04	1.17	0.04	0.01	14.76	0.08	1.78	4.08	19.59	5.70	98.67
Line 1 FN14-B-2-L4	0.73	46.65	3.44	0.07	0.00	12.81	0.15	0.06	6.40	22.34	5.94	98.59
Line 2 FN14-B-2-L4	0.74	46.57	3.42	0.16	0.01	12.76	0.21	0.07	6.34	22.24	5.76	98.29
Line 3 FN14-B-2-L4	0.72	46.94	3.56	0.11	0.00	13.08	0.17	0.03	6.39	22.20	5.57	98.77
Line 4 FN14-B-2-L4	0.75	47.09	3.40	0.10	0.01	13.10	0.19	0.11	6.29	22.44	5.54	99.02
Line 5 FN14-B-2-L4	0.67	46.73	3.31	0.14	0.01	13.07	0.21	0.05	6.34	22.14	5.96	98.63
Line 6 FN14-B-2-L4	0.60	46.36	3.55	0.11	0.00	12.89	0.16	0.04	6.10	22.15	6.27	98.22
Line 7 FN14-B-2-L4	0.57	45.93	3.85	0.17	0.00	12.90	0.19	0.06	6.06	22.38	6.52	98.63
Line 8 FN14-B-2-L4	0.60	45.58	3.89	0.15	0.00	12.63	0.13	0.05	6.05	22.28	7.00	98.36
Line 9 FN14-B-2-L4	0.52	47.63	3.02	0.14	0.01	13.82	0.15	0.31	5.17	22.47	5.54	98.78
Line 10 FN14-B-2-L4	0.72	47.97	2.36	0.06	0.00	14.16	0.12	0.69	4.84	22.28	5.38	98.57
Line 11 FN14-B-2-L4	0.89	48.31	1.85	0.11	0.00	14.09	0.16	1.22	4.46	21.86	5.56	98.51
Line 12 FN14-B-2-L4	0.86	48.25	1.93	0.11	0.01	14.07	0.11	1.18	4.48	21.62	5.72	98.34
Line 13 FN14-B-2-L4	0.90	48.82	1.87	0.11	0.04	14.00	0.17	1.27	4.59	21.60	5.82	99.18
Line 14 FN14-B-2-L4	0.84	48.85	1.94	0.07	0.02	14.20	0.10	1.19	4.31	21.54	5.36	98.42
Line 15 FN14-B-2-L4	1.17	50.26	1.13	0.11	0.01	15.08	0.12	1.47	4.13	19.97	5.04	98.48
Line 16 FN14-B-2-L4	1.29	50.20	1.19	0.13	0.01	15.13	0.15	1.47	4.17	19.55	5.29	98.57
Line 17 FN14-B-2-L4	1.34	50.69	1.17	0.10	0.01	15.12	0.17	1.42	4.21	19.60	5.14	98.96
Line 18 FN14-B-2-L4	1.38	50.75	1.28	0.09	0.00	15.11	0.17	1.40	4.16	19.64	5.18	99.15
Line 19 FN14-B-2-L4	1.28	50.53	0.98	0.08	0.01	15.09	0.09	1.53	4.14	19.47	5.13	98.34
Line 20 FN14-B-2-L4	1.18	50.74	1.13	0.07	0.00	15.02	0.14	1.39	4.05	19.55	5.03	98.30
Line 21 FN14-B-2-L4	1.35	50.85	1.05	0.07	0.01	15.20	0.12	1.44	4.02	19.36	5.01	98.47
Line 22 FN14-B-2-L4	1.31	50.39	1.05	0.10	0.03	15.29	0.11	1.49	4.14	19.47	5.04	98.42
Line 23 FN14-B-2-L4	1.31	50.65	1.03	0.07	0.00	15.09	0.14	1.44	4.19	19.21	4.98	98.11
Line 24 FN14-B-2-L4	1.39	50.26	1.03	0.09	0.00	15.03	0.13	1.48	4.24	19.50	5.21	98.36
Line 25 FN14-B-2-L4	1.43	50.32	1.02	0.08	0.02	14.82	0.11	1.66	4.01	19.33	5.36	98.16
Line 1 FN18-1B-1-L1	0.87	45.11	3.78	0.07	0.05	12.50	0.15	0.49	5.91	22.49	7.51	98.93
Line 2 FN18-1B-1-L1	0.85	43.80	4.15	0.11	0.02	11.66	0.19	0.29	6.52	22.49	8.86	98.94
Line 3 FN18-1B-1-L1	0.91	42.72	4.47	0.15	0.04	10.59	0.19	0.05	7.50	22.54	9.44	98.59
Line 4 FN18-1B-1-L1	0.83	41.35	5.31	0.10	0.02	9.77	0.22	0.00	8.46	22.39	10.48	98.93
Line 5 FN18-1B-1-L1	0.84	41.53	5.35	0.10	0.00	9.97	0.21	0.00	8.03	22.47	10.38	98.88
Line 6 FN18-1B-1-L1	0.84	40.78	5.68	0.10	0.01	9.69	0.17	0.02	7.93	22.52	10.77	98.51
Line 7 FN18-1B-1-L1	0.67	41.07	5.59	0.12	0.00	9.67	0.19	0.06	7.98	22.62	10.66	98.64
Line 8 FN18-1B-1-L1	0.66	42.94	4.51	0.13	0.05	10.58	0.24	0.02	8.10	22.58	9.79	99.59
Line 9 FN18-1B-1-L1	0.69	40.97	3.62	0.10	0.70	10.16	0.33	0.11	7.52	17.33	11.02	92.55
Line 10 FN18-1B-1-L1	0.66	41.33	4.88	0.12	0.07	10.60	0.33	0.03	7.76	22.01	11.41	99.19
Line 11 FN18-1B-1-L1	0.66	41.36	4.96	0.10	0.02	10.14	0.33	0.04	7.64	22.55	10.81	98.61
Line 12 FN18-1B-1-L1	0.71	45.39	3.47	0.09	0.02	12.14	0.25	0.03	6.56	22.56	7.56	98.78

Spot Analyses	Na2O	SiO2	TiO2	MnO	K2O	MgO	P2O5	Cr2O3	FeO	CaO	Al2O3	Total
Line 13 FN18-1B-1-L1	0.71	46.70	3.07	0.05	0.03	12.84	0.15	0.08	6.46	22.88	6.71	99.67
Line 14 FN18-1B-1-L1	0.55	47.08	2.51	0.08	0.00	13.48	0.17	0.11	6.28	22.79	6.22	99.27
Line 15 FN18-1B-1-L1	0.54	47.52	2.10	0.13	0.01	13.51	0.21	0.64	6.32	22.61	5.64	99.23
Line 16 FN18-1B-1-L1	0.48	45.19	2.81	0.10	0.00	12.29	0.17	0.73	6.96	22.77	7.29	98.79
Line 17 FN18-1B-1-L1	0.68	45.84	2.72	0.12	0.01	12.78	0.16	0.74	7.05	22.24	7.21	99.55
Line 18 FN18-1B-1-L1	0.96	49.48	1.29	0.04	0.02	14.35	0.17	0.85	5.93	20.86	5.53	99.48
Line 19 FN18-1B-1-L1	0.90	49.30	1.13	0.04	0.02	14.77	0.16	0.82	5.80	20.62	5.18	98.74
Line 20 FN18-1B-1-L1	0.89	49.12	1.21	0.10	0.01	14.58	0.12	0.73	5.94	20.92	5.42	99.05
Line 21 FN18-1B-1-L1	0.91	48.64	1.56	0.10	0.00	14.11	0.17	0.79	6.06	21.19	5.89	99.43
Line 22 FN18-1B-1-L1	0.98	49.56	1.10	0.15	0.01	14.68	0.16	0.96	5.97	20.26	5.72	99.55
Line 23 FN18-1B-1-L1	1.00	49.40	1.06	0.13	0.00	14.66	0.12	1.01	5.74	20.24	5.89	99.25
Line 24 FN18-1B-1-L1	0.92	49.43	1.01	0.08	0.00	14.65	0.14	0.99	5.57	20.26	5.98	99.03
Line 25 FN18-1B-1-L1	1.09	48.74	1.40	0.10	0.01	14.22	0.11	0.61	6.11	20.27	6.22	98.88
Line 1 FN18-1B-1-L2	0.80	46.36	3.23	0.07	0.00	12.77	0.13	0.39	5.64	22.89	6.47	98.75
Line 2 FN18-1B-1-L2	0.82	46.63	3.28	0.07	0.00	12.66	0.15	0.36	5.82	22.67	6.57	99.03
Line 3 FN18-1B-1-L2	0.73	45.76	3.41	0.08	0.00	12.05	0.21	0.30	6.46	22.56	7.23	98.79
Line 4 FN18-1B-1-L2	0.83	43.19	4.04	0.17	0.00	10.66	0.28	0.06	7.65	22.19	9.47	98.54
Line 5 FN18-1B-1-L2	0.53	46.03	2.63	0.10	0.00	12.89	0.15	0.27	6.43	22.65	6.75	98.43
Line 6 FN18-1B-1-L2	0.53	47.36	2.20	0.03	0.00	13.42	0.14	0.57	6.29	22.53	5.70	98.77
Line 7 FN18-1B-1-L2	0.56	46.02	2.28	0.07	0.01	13.08	0.12	0.50	6.70	22.63	6.37	98.33
Line 8 FN18-1B-1-L2	0.48	46.35	2.41	0.11	0.01	12.91	0.15	0.63	6.83	22.55	6.58	99.00
Line 9 FN18-1B-1-L2	0.53	46.43	2.35	0.07	0.00	12.99	0.15	0.70	6.71	22.72	6.51	99.16
Line 10 FN18-1B-1-L2	0.56	46.71	2.19	0.15	0.00	13.13	0.12	0.80	6.49	22.68	6.16	98.98
Line 11 FN18-1B-1-L2	0.52	45.86	2.50	0.07	0.00	12.80	0.12	0.88	6.92	22.81	6.71	99.19
Line 12 FN18-1B-1-L2	0.57	45.66	2.56	0.08	0.00	12.68	0.17	0.73	6.69	22.77	6.83	98.74
Line 13 FN18-1B-1-L2	0.50	45.23	2.30	0.00	0.10	12.41	0.24	0.58	6.66	20.99	7.86	96.86
Line 14 FN18-1B-1-L2	0.47	45.63	2.43	0.06	0.01	12.84	0.17	0.64	7.14	22.22	7.31	98.92
Line 15 FN18-1B-1-L2	0.55	46.30	2.46	0.08	0.00	12.60	0.12	0.78	7.06	22.86	7.03	99.85
Line 16 FN18-1B-1-L2	0.49	46.51	2.05	0.09	0.00	13.00	0.15	0.87	6.62	22.96	6.52	99.26
Line 17 FN18-1B-1-L2	0.48	47.32	1.89	0.04	0.01	13.31	0.18	0.82	6.38	22.69	6.08	99.20
Line 18 FN18-1B-1-L2	0.54	48.19	1.62	0.13	0.01	13.88	0.19	0.69	5.84	22.68	5.68	99.46
Line 19 FN18-1B-1-L2	0.45	48.87	1.36	0.08	0.00	14.36	0.12	0.69	5.62	22.75	4.69	98.99
Line 20 FN18-1B-1-L2	0.55	48.70	1.65	0.11	0.02	14.20	0.17	0.63	5.79	22.75	5.10	99.67
Line 21 FN18-1B-1-L2	0.50	47.92	1.73	0.14	0.01	14.01	0.17	0.71	5.95	22.58	5.84	99.57
Line 22 FN18-1B-1-L2	0.56	47.71	1.73	0.08	0.00	13.97	0.14	0.77	5.84	22.68	5.66	99.13
Line 23 FN18-1B-1-L2	0.54	48.31	1.51	0.12	0.00	14.01	0.14	0.72	5.54	22.63	5.47	98.98
Line 24 FN18-1B-1-L2	0.50	48.35	1.63	0.06	0.00	14.05	0.10	0.87	5.47	22.53	5.59	99.16
Line 25 FN18-1B-1-L2	0.43	48.44	1.57	0.05	0.01	14.16	0.14	0.83	5.59	22.66	5.38	99.27
Line 1 FN18-1B-2-L3	0.75	45.55	3.67	0.05	0.04	12.76	0.19	0.47	5.65	22.71	7.28	99.11
Line 2 FN18-1B-2-L3	0.81	45.43	3.58	0.08	0.00	12.73	0.21	0.56	5.79	22.64	7.40	99.22
Line 3 FN18-1B-2-L3	0.75	45.98	3.58	0.10	0.00	12.48	0.17	0.43	5.80	22.70	7.47	99.47
Line 4 FN18-1B-2-L3	0.75	45.75	3.75	0.07	0.01	12.39	0.22	0.44	5.81	22.57	7.26	99.03
Line 5 FN18-1B-2-L3	0.80	45.65	3.82	0.12	0.00	12.37	0.19	0.49	5.83	22.46	7.34	99.07
Line 6 FN18-1B-2-L3	0.77	45.74	3.47	0.07	0.00	12.37	0.15	0.44	6.18	22.62	7.15	98.97
Line 7 FN18-1B-2-L3	0.79	45.54	3.78	0.09	0.00	12.29	0.19	0.41	6.29	22.64	7.43	99.46
Line 8 FN18-1B-2-L3	0.75	44.64	3.84	0.10	0.00	11.67	0.20	0.22	6.84	22.73	8.46	99.45
Line 9 FN18-1B-2-L3	0.68	45.02	3.62	0.09	0.00	11.20	0.17	0.14	7.48	22.42	8.50	99.32
Line 10 FN18-1B-2-L3	0.68	45.07	3.44	0.11	0.01	11.21	0.14	0.13	8.05	22.65	8.29	99.78
Line 11 FN18-1B-2-L3	0.75	43.71	3.80	0.15	0.00	10.30	0.18	0.13	8.24	22.56	9.53	99.35
Line 12 FN18-1B-2-L3	0.73	43.84	3.91	0.13	0.00	10.38	0.20	0.09	8.26	22.53	9.62	99.69
Line 13 FN18-1B-2-L3	0.72	43.11	4.25	0.11	0.00	10.26	0.23	0.05	8.13	22.48	9.98	99.31
Line 14 FN18-1B-2-L3	0.73	42.94	4.34	0.06	0.01	10.82	0.25	0.04	7.67	22.32	10.11	99.30
Line 15 FN18-1B-2-L3	0.56	45.50	3.25	0.07	0.00	12.05	0.18	0.14	6.71	22.63	7.84	98.92

Spot Analyses	Na2O	SiO2	TiO2	MnO	K2O	MgO	P2O5	Cr2O3	FeO	CaO	Al2O3	Total
Line 16 FN18-1B-2-L3	0.47	46.44	2.85	0.07	0.00	13.06	0.17	0.19	6.58	22.88	6.65	99.35
Line 17 FN18-1B-2-L3	0.48	47.72	2.22	0.14	0.01	13.96	0.21	0.47	6.22	22.80	5.33	99.56
Line 18 FN18-1B-2-L3	0.56	47.87	1.96	0.12	0.01	14.02	0.19	0.59	6.06	22.34	5.31	99.03
Line 19 FN18-1B-2-L3	0.62	47.27	2.12	0.07	0.01	13.54	0.17	0.69	6.62	22.44	5.94	99.49
Line 20 FN18-1B-2-L3	0.58	46.66	2.32	0.09	0.02	13.27	0.12	0.95	6.51	22.84	6.11	99.47
Line 21 FN18-1B-2-L3	0.53	48.23	1.83	0.08	0.05	14.00	0.17	1.01	5.83	22.56	5.17	99.45
Line 22 FN18-1B-2-L3	0.70	48.02	1.92	0.08	0.42	12.72	0.28	0.83	6.10	20.70	6.99	98.76
Line 23 FN18-1B-2-L3	0.50	48.65	1.64	0.04	0.00	13.76	0.12	1.15	5.30	22.77	5.45	99.38
Line 24 FN18-1B-2-L3	0.47	48.65	1.60	0.08	0.01	13.74	0.18	1.18	5.60	22.73	5.55	99.79
Line 25 FN18-1B-2-L3	0.47	48.05	1.61	0.12	0.00	13.85	0.12	1.16	5.51	22.99	5.53	99.41
Line 1 FN18-1B-2-L4	0.84	45.65	3.69	0.14	0.02	12.44	0.16	0.35	6.11	22.68	7.12	99.20
Line 2 FN18-1B-2-L4	0.82	45.67	3.75	0.11	0.02	12.29	0.19	0.31	6.43	22.60	7.14	99.33
Line 3 FN18-1B-2-L4	0.77	45.08	4.02	0.08	0.00	11.89	0.18	0.24	6.34	22.56	8.20	99.37
Line 4 FN18-1B-2-L4	0.76	45.01	3.87	0.03	0.01	11.95	0.16	0.19	6.51	22.69	8.15	99.32
Line 5 FN18-1B-2-L4	0.70	43.20	3.53	0.10	0.02	11.07	0.13	0.08	6.76	21.14	7.88	94.60
Line 6 FN18-1B-2-L4	0.83	43.43	4.26	0.13	0.04	10.50	0.21	0.00	8.15	22.44	8.76	98.75
Line 7 FN18-1B-2-L4	0.78	42.80	4.69	0.09	0.00	10.01	0.15	0.00	9.02	22.29	9.87	99.69
Line 8 FN18-1B-2-L4	0.62	42.60	4.45	0.14	0.01	9.77	0.18	0.02	8.82	22.22	10.11	98.94
Line 9 FN18-1B-2-L4	0.68	42.96	4.25	0.10	0.02	10.30	0.23	0.05	8.39	22.54	9.59	99.12
Line 10 FN18-1B-2-L4	0.71	43.07	4.44	0.07	0.01	10.59	0.26	0.06	8.16	21.99	9.63	99.00
Line 11 FN18-1B-2-L4	0.69	45.36	3.38	0.10	0.00	12.12	0.19	0.18	6.75	22.47	7.86	99.09
Line 12 FN18-1B-2-L4	0.48	46.46	2.01	0.07	0.00	13.39	0.18	0.49	6.02	22.54	5.12	96.76
Line 13 FN18-1B-2-L4	0.51	47.01	2.00	0.13	0.02	13.42	0.16	0.45	6.47	22.81	5.83	98.80
Line 14 FN18-1B-2-L4	0.52	46.85	2.19	0.06	0.02	13.16	0.16	0.44	6.91	22.83	6.17	99.31
Line 15 FN18-1B-2-L4	0.52	46.87	2.19	0.10	0.00	13.33	0.17	0.60	6.49	22.99	5.99	99.26
Line 16 FN18-1B-2-L4	0.56	46.11	2.48	0.11	0.00	13.02	0.19	0.62	6.60	22.93	6.41	99.03
Line 17 FN18-1B-2-L4	0.55	45.64	2.55	0.10	0.02	12.97	0.13	0.45	6.84	22.65	6.82	98.72
Line 18 FN18-1B-2-L4	0.55	46.19	2.51	0.10	0.00	12.83	0.16	0.42	6.97	22.52	6.83	99.08
Line 19 FN18-1B-2-L4	0.62	46.60	2.41	0.09	0.00	13.13	0.11	0.48	6.69	22.43	6.44	99.01
Line 20 FN18-1B-2-L4	0.60	47.98	1.93	0.04	0.01	14.16	0.14	0.68	6.28	22.45	5.12	99.39
Line 21 FN18-1B-2-L4	0.66	47.92	1.77	0.06	0.01	14.14	0.14	0.66	6.16	21.96	4.94	98.42
Line 22 FN18-1B-2-L4	0.69	48.79	1.65	0.09	0.00	14.38	0.14	0.66	6.16	21.38	5.48	99.42
Line 23 FN18-1B-2-L4	0.79	49.62	1.15	0.13	0.00	14.73	0.13	0.56	6.14	20.88	4.79	98.92
Line 24 FN18-1B-2-L4	0.84	49.35	1.19	0.11	0.02	15.04	0.11	0.59	6.11	20.36	5.17	98.90
Line 25 FN18-1B-2-L4	0.86	49.09	1.33	0.12	0.01	14.50	0.12	0.59	6.45	20.52	5.82	99.40

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