Supplemental text and figures for: Compositional trends in Ba-, Ti-, and Cl-rich micas from metasomatized mantle rocks of the Gföhl Unit, Bohemian Massif, Austria

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Content: This material contains a petrographic description of garnet pyroxenites including figures and ranges of chemical compositions of each mineral phases.

The samples of garnet pyroxenites collected from the Dunkelsteiner Wald granulite massif (prefix DS) show some variations in mineral chemistry even within one locality. Therefore, the individual samples from the Dunkelsteiner Wald massif and the chemistry of their major mineral phases are described separately. Samples of garnet pyroxenite from the St. Leonhard massif (prefix SL) were all collected from a single outcrop, their characteristics are very similar and therefore, they are described together. GPX coordinates of the individual sites and representative analyses of the main mineral phases are given in Supplementary file Supp1.

DS025 – The primary mineral assemblage is represented by of up to 3 mm sized garnet porphyroblasts in a granoblastic matrix dominated by clinopyroxene with an average grain size of 1.3 mm. Garnets contain inclusions of clinopyroxene and rarely kyanite, which can be surrounded with a thin rim of sapphirine. Clinopyroxene grains in the matrix contain orthopyroxene exsolution lamellae. The dominant clinopyroxene-garnet mineral assemblage is locally replaced by orthopyroxene, amphibole, plagioclase, and spinel.

Detailed investigation of the mineral chemistry revealed the existence of zones/layers with systematic variations of garnet chemistry. One layer is characterized by garnet showing significant enrichment in Ca and depletion in Mg in the core compared to the rim. Fe is characterized by a compositional plateau followed by an increase at the outer rim: $Py_{42.9\rightarrow54.4}Alm_{20.5\rightarrow24.7}Grs_{36.0\rightarrow20.3}Sps_{0.5\rightarrow0.6}$, $XFe_{0.324\rightarrow0.31}$. The other layer contains garnet crystals characterized by a compositional plateau in their central parts and are noticeably Ca poorer and Mg richer compared to the garnets from the first layer. The central part of these garnets is characterized by a slight increase of Ca and decrease of Mg in the direction from core to rim. This is than followed by a more abrupt increase of Mg and a subsequent drop towards the outermost rim accompanied by an increase of Fe and a decrease of Ca contents with $Py_{63.1\rightarrow61.6\rightarrow(63.2)\rightarrow61.6}Alm_{21.2\rightarrow22.8\rightarrow25.3}Grs_{15.3\rightarrow16.3\rightarrow12.6}Sps_{0.4\rightarrow0.5\rightarrow0.5}$, $XFe_{0.25\rightarrow0.27\rightarrow0.29}$.

Clinopyroxene forming the matrix of both layers has the same chemical composition characterized by a core to rim Na decrease and Ca increase in the range $CaTs_{5.4\rightarrow10.3}Jd_{17.9\rightarrow11.7}XFe_{0.14\rightarrow0.13}$; $Al_{\sim0.3}$.

The mineral phases of the secondary mineral assemblage have the following compositional ranges: orthopyroxene: $XFe_{0.16–0.17}$, $Al_{0.2–0.4}$ (a.p.f.u); plagioclase: $Ab_{55.2–68.7}$, amphibole: $XFe_{0.13–0.19}$, $Ba_{0.0–0.1}Ti_{0.1–0.3}Cl_{0.0–0.4}Si_{5.9–6.2}$ (a.p.f.u).

An overview of the mineral assemblage of sample DS025 including composition maps showing the variability of garnet composition and Na-enriched cores of clinopyroxene is shown in the Figure OM1.

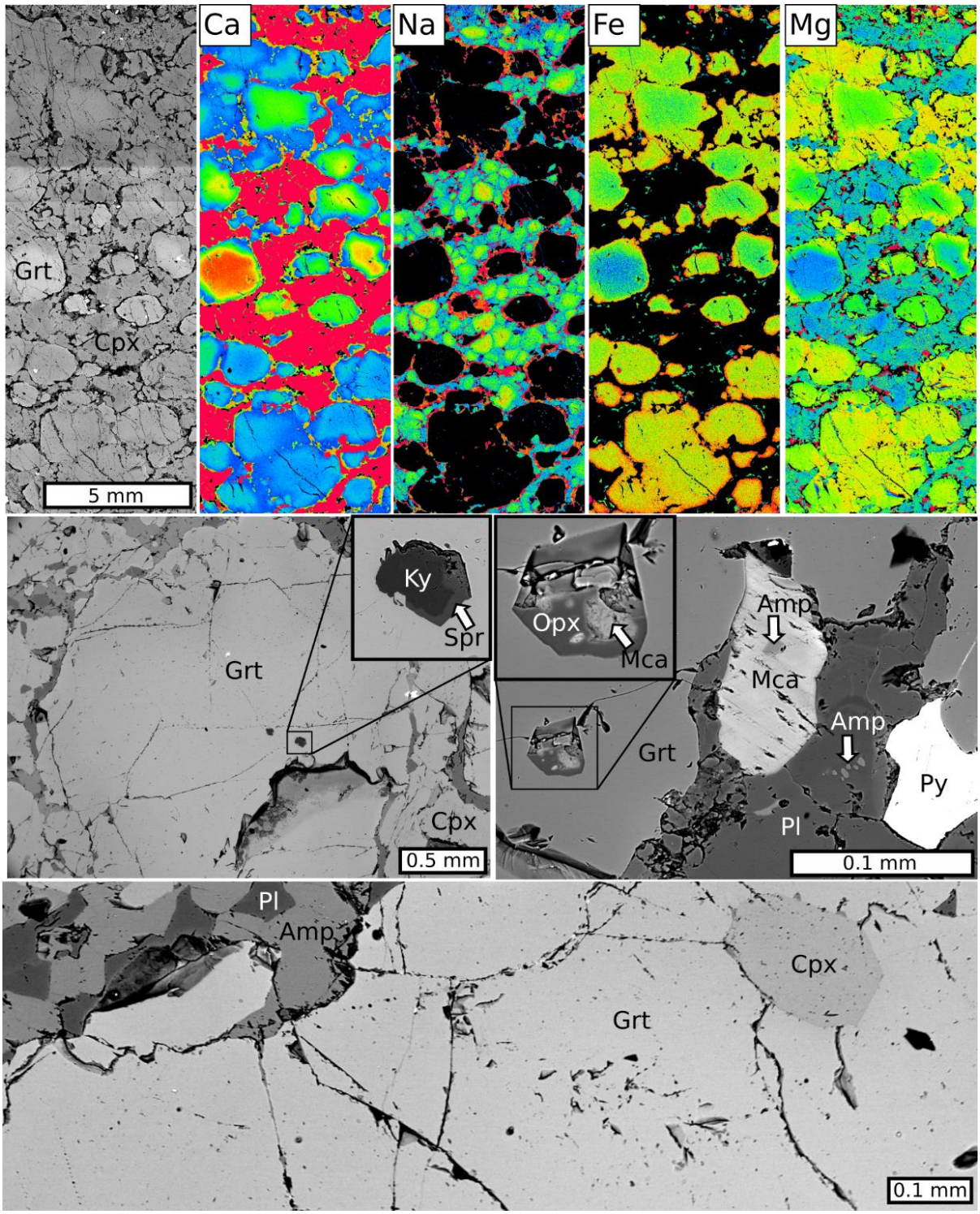

Figure OM1. Overview of the mineral assemblage of a garnet pyroxenite (sample DS025) including composition maps of Ca, Na, Fe, Mg showing zones with variations of garnet chemistry and Na-enriched cores of clinopyroxene.

DS025-17A – The primary mineral assemblage is formed by up to 2.2 mm sized garnet porphyroblasts with occasional inclusions of clinopyroxene and kyanite, and granoblastic matrix consisting dominantly of clinopyroxene (~0.7 mm) with orthopyroxene exsolution lamellae. Small amounts of orthopyroxene,

amphibole, plagioclase and rarely spinel are present in the matrix mainly around garnet. The sample is characterized by a gradual transition of this granoblastic matrix into a coarse-grained clinopyroxene-plagioclase (± orthopyroxene ± amphibole) symplectitic matrix with average grain size of 0.2 mm.

Garnet shows a systematic variation of its composition with respect to its textural position. Garnet in the granoblastic clinopyroxene matrix is characterized by a compositional plateau with a minor decrease in Mg and Ca and an increase in Fe at the rim: $Py_{62.1\rightarrow57.3}Alm_{24.1\rightarrow29.0}Grs_{13.2\rightarrow12.9}Sps_{0.6\rightarrow0.9}$, $XFe_{0.28\rightarrow0.34}$. Clinopyroxene in this area is characterized by core to rim Na decrease and Ca increase with compositions in the range of $CaTs_{4.2\rightarrow10.5}$ $Jd_{24.1\rightarrow15.1}XFe_{0.15\rightarrow0.13}$, $Al_{\sim0.3}$ (a.p.f.u).

Garnet from clinopyroxene-plagioclase symplectitic matrix has higher Ca and lower Mg contents as compared to garnet from the granoblastic matrix. It is characterized by a compositional plateau with Mg and Fe increase and Ca decrease at the rim: $Py_{41.4\rightarrow49.4}Alm_{22.3\rightarrow33.2}Grs_{35.8\rightarrow16.4}Sps_{0.6\rightarrow1.1}$, $XFe_{0.35\rightarrow0.40}$.

Clinopyroxene in the coarse-grained symplectite with plagioclase has compositions in the range: $CaTs_{8.3–14.6}Jd_{12.2–17.2}XFe_{0.16–0.22,}$ $Al_{\sim0.4}$ (a.p.f.u). Other minor mineral phases present in the granoblastic and symplectitic matrix representing a secondary mineral association have similar chemical compositions with the following compositional ranges: orthopyroxene: $XFe_{0.17–0.20}$; $Al_{0.1–0.2}$ (a.p.f.u), plagioclase: $Ab_{44.1–66.7}$, amphibole: $XFe_{0.13–0.23}$, $Ba_{0.0–0.1}Ti_{0.1–0.3}Cl_{0.0–0.4}Si_{5.9–6.1}$, spinel: $XFe_{25.3–41.7}$; $Al_{1.9–2.0}Cr_{\sim0.0}$ (a.p.f.u).

An overview of the mineral assemblage of sample DS025-17-A including composition maps showing the variability of garnet composition and Na-enriched cores of clinopyroxene is shown in the Figure OM2.

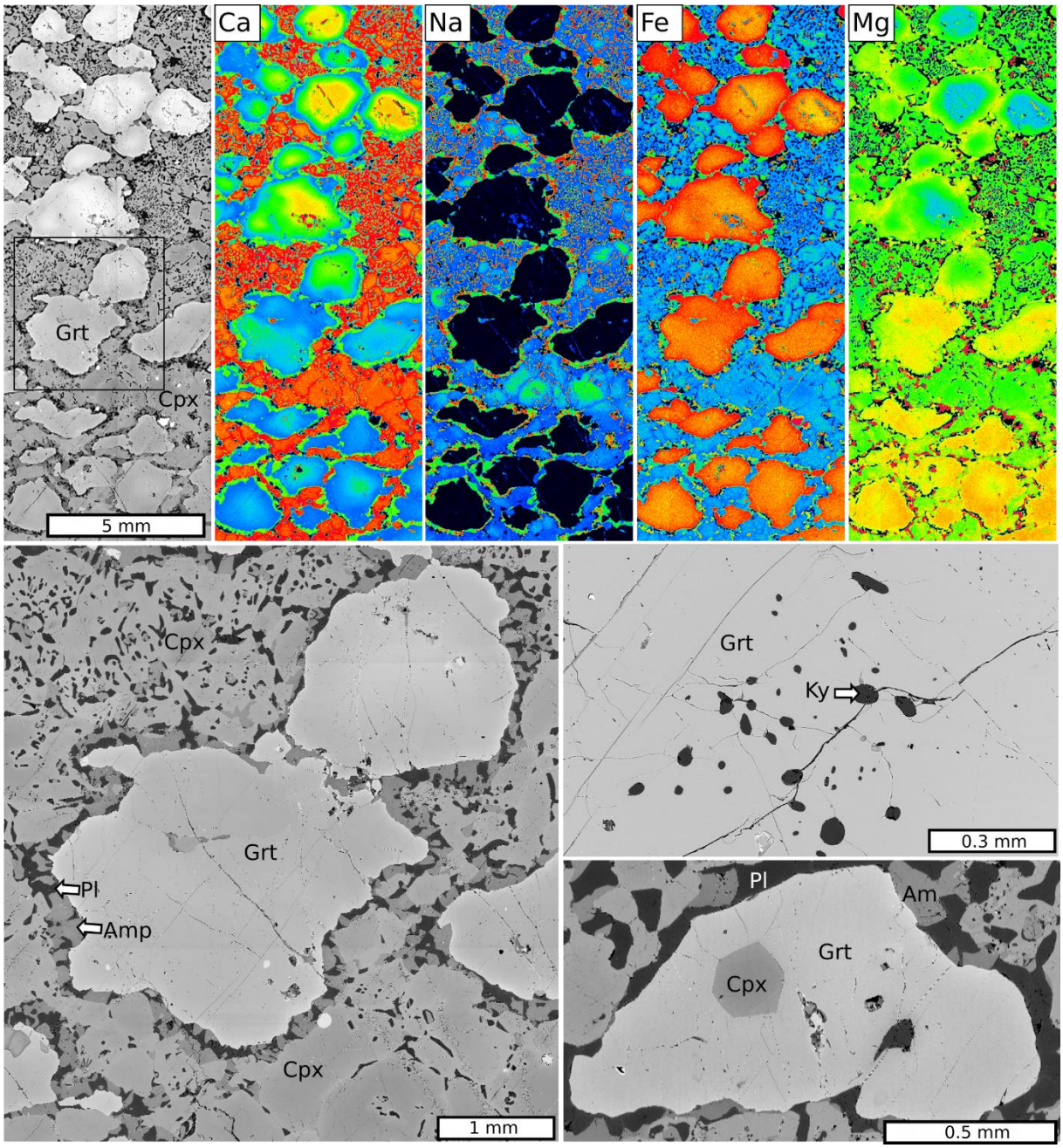

Figure OM2. Overview of mineral assemblage of garnet pyroxenite (sample DS025-17-A) including composition maps of Ca, Na, Mg, Fe showing the change of garnet chemistry with textural change and Na-enriched cores of preserved clinopyroxene.

DS072C – In this sample, the primary mineral assemblage is formed by up to 2.8 mm sized garnet porphyroblasts with inclusions of clinopyroxene and rutile in clinopyroxene granoblastic matrix with average grain size of 1.2 mm. Garnet is further surrounded by an up to 0.2 mm wide rim of plagioclase and fine-grained symplectite of clinopyroxene, orthopyroxene, spinel, and amphibole. Zoned Ba-rich micas occur around garnets in the matrix associated with the symplectites.

Similarly, to the previous samples, zones/areas defined by a gradual transition in the chemical composition of garnet are observed. These variations are characterized by the alternation of areas with Mg-rich and Ca-poor garnet and areas with Ca-rich and Mg poor garnet.

Garnets from both zones are characterized by similar trends in the chemical composition but with different absolute values, which is defined by the compositional plateau in the core region followed by Mg and Ca decrease and Fe increase at the rim, Mg-rich garnets: $Py_{63.8\rightarrow61.0}Alm_{21.6\rightarrow26.5}Grs_{14.1\rightarrow11.8}Sps_{0.4\rightarrow0.7}$, $XFe_{0.25\rightarrow0.30}$; Ca-rich garnets: $Py_{58.7\rightarrow56.1}Alm_{21.0\rightarrow31.3}Grs_{19.9\rightarrow11.4}Sps_{0.5\rightarrow1.2,}$ $XFe_{0.26\rightarrow0.36}$.

The composition of matrix clinopyroxene as well as of clinopyroxene inclusions in garnet is characterized by a core to rim decrease of Na and Fe and a concommitant increase of Ca: matrix $CaTs_{5.0\rightarrow11.0}Jd_{20.4\rightarrow11.1}XFe_{0.12\rightarrow0.11;}$ $Al_{\sim0.3}$ (a.p.f.u); garnet-hosted inclusion in Grt: $CaTs_{4.0\rightarrow10.4}Jd_{20.1\rightarrow19.4}XFe_{0.12\rightarrow0.12}$, $Al_{\sim0.3}$ (a.p.f.u).

Mineral phases pertaining to the secondary mineral assemblages have the following compositional ranges: clinopyroxene: $CaTs_{9.4–10.5}Jd_{11.6–12.9}XFe_{0.13–0.13}$, $Al_{\sim0.3}$ (a.p.f.u), orthopyroxene: $XFe_{0.16–0.16}$, $Al_{\sim0.2}$ (a.p.f.u), plagioclase: $Ab_{56.4–65.8}$, amphibole: $XFe_{0.16–0.18}$, $Ba_{\sim0.0}Ti_{\sim0.2}Cl\sim_{0.0}Si_{5.9–6.1}$ (a.p.f.u), spinel: $XFe_{\sim0.29}$; $Al_{\sim2.0}Cr_{\sim0.0}$ (a.p.f.u).

An overview of the mineral assemblage of sample DS072C including composition maps showing variability of garnet composition and Na-enriched cores of clinopyroxene is shown in the Figure OM3.

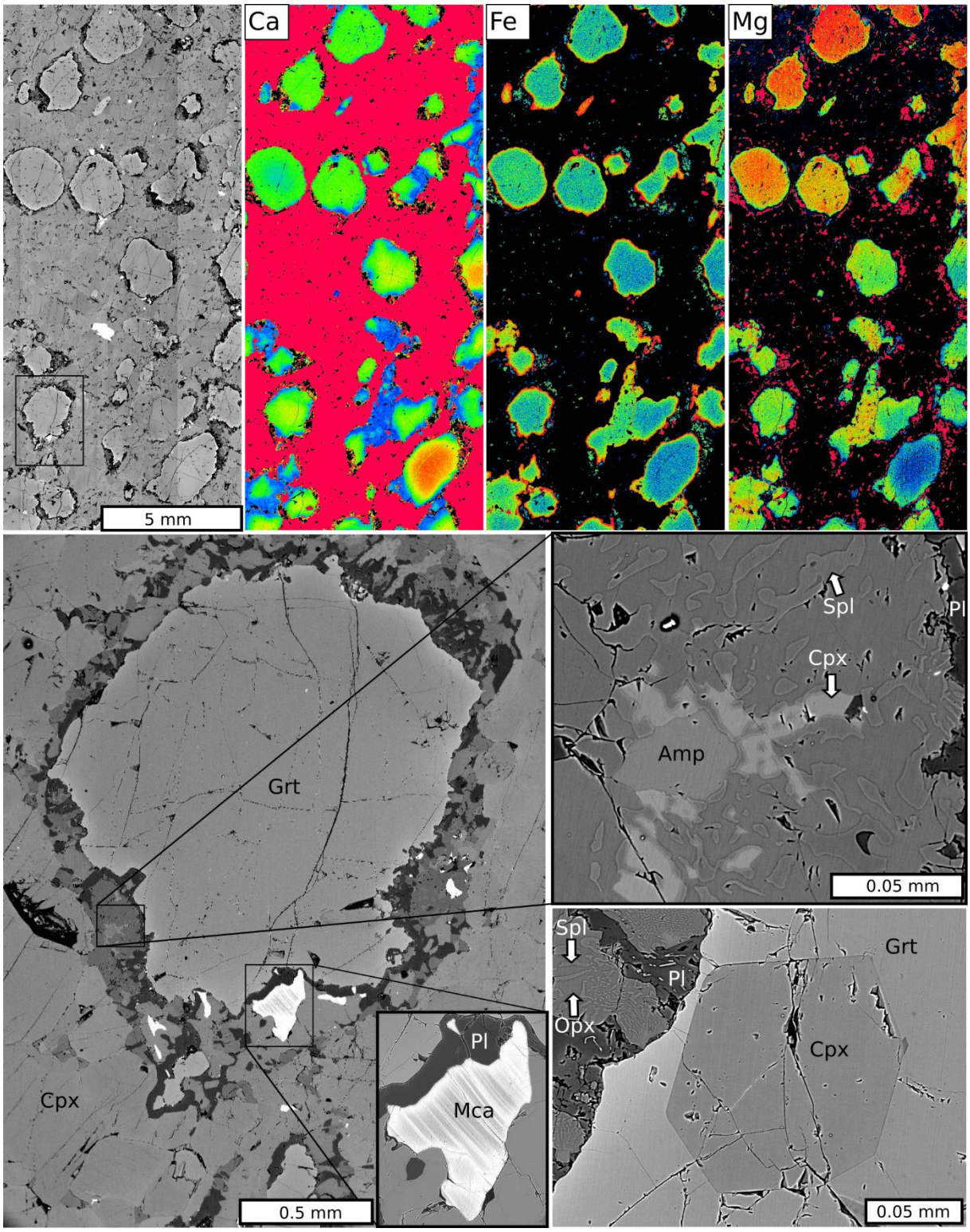

Figure OM3. Overview of mineral assemblage of garnet pyroxenite (sample DS072) including composition maps of Ca, Fe and Mg showing variability of garnet chemistry.

DS142C – The primary mineral assemblage is formed by up to 2.4 mm sized garnet porphyroblasts with inclusions of clinopyroxene and rutile, and by a granoblastic matrix, which is predominantly comprised of

clinopyroxene with an average grain size of 0.5 mm. The clinopyroxene contains orthopyroxene exsolution lamellae. The garnets are surrounded by thin rims (~0.2 mm) of coarse grained symplectite comprised of plagioclase, orthopyroxene, and amphibole with an average grain size of about 0.13 mm. This coarse-grained symplectite tends to be accompanied by fine-grained symplectite of orthopyroxene, spinel, amphibole, and clinopyroxene.

The garnets are characterized by a compositional plateau in the central part with Ca and Mg decreasing and Fe increasing towards the rim: $Py_{57.9\rightarrow54.8\rightarrow}Alm_{14.6\rightarrow21.9}Grs_{22.9\rightarrow18.0}Sps_{0.3\rightarrow0.8}$, $XFe_{0.25\rightarrow0.33}$. Matrix clinopyroxene and garnet hosted clinopyroxene inclusions are characterized by core to rim increase of the Ca- and decrease of the Na contents: matrix clinopyroxene: $CaTs_{10.0\rightarrow17.8}Jd_{24.8\rightarrow19.3}XFe_{\sim0.13}$, $Al_{\sim0.4}$ (a.p.f.u); garnet hosted clinopyroxene inclusion: $CaTs_{6.4\rightarrow12.7}Jd_{29.0\rightarrow27.1}XFe_{0.10\rightarrow0.11}$, $Al_{0.4–0.5}$ (a.p.f.u).

Mineral phases pertaining to the secondary mineral association have compositions within the following ranges: clinopyroxene in fine-grained symplectite: $CaTs_{10.0–12.1}Jd_{9.1–12.2}XFe_{0.09–0.12}$, $Al_{0.3–0.4}$ (a.p.f.u), orthopyroxene: $XFe_{0.12–0.16}$, $Al_{\sim0.2}$ (a.p.f.u), plagioclase: $Ab_{56.5–67.1}$, amphibole: $XFe_{0.13–0.15}$, $Ba_{\sim0.0}Ti_{0.1–0.3}Cl_{\sim0.0}Si_{5.9–6.0}$ (a.p.f.u). spinel: $XFe_{0.22–0.27}$; $Al_{\sim2}Cr_{\sim0}$ (a.p.f.u).

An overview of the mineral assemblage of sample DS142C including composition maps showing the variability of garnet composition and Na-enriched cores of clinopyroxene is shown in the Figure OM4.

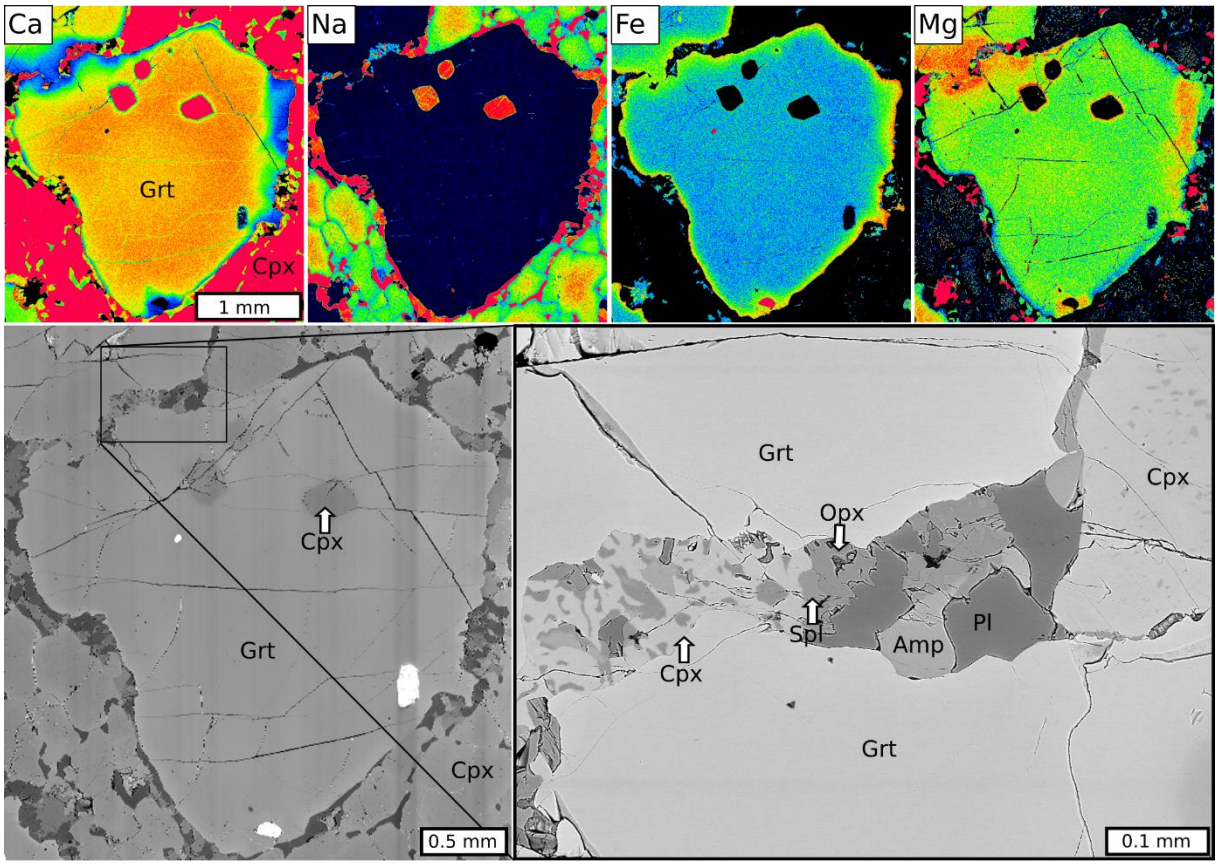

Figure OM4. Representative area of garnet pyroxenite (sample DS142C) with garnet porphyroblast and fine-grained symplectites in the surrounding matrix. Composition maps of Ca, Na, Fe and Mg show zonality of garnet and elevated Na-contents in the clinopyroxene cores.

DS148A – The primary mineral assemblage is formed by up to 5 mm sized garnet porphyroblasts surrounded by clinopyroxene (~1mm) with orthopyroxene exsolution lamellae forming the granoblastic matrix. Garnet contains inclusions of clinopyroxene with amphibole and occasionally sapphirine and chlorite at the rims. Garnet is replaced to variable extent by fine-grained symplectites composed of spinel, amphibole, clinopyroxene and sometimes accompanied by chlorite. Garnet is crosscut by cracks filled with chlorite. The matrix also contains subordinate amounts of amphibole and orthopyroxene with an average grain size of about 0.1 mm.

The garnet cores are relatively Ca-rich and Fe and Mg-poor as compared to the rims: $Py_{50.4\rightarrow52.5}Alm_{21.0\rightarrow29.2}Grs_{28.1\rightarrow17.5}Sps_{0.5\rightarrow0.8}$, $XFe_{0.29\rightarrow0.36}$. Matrix clinopyroxene and clinopyroxene inclusions in garnet show weak compositional zoning with a core to rim Ca increase and Na and Fe decrease: matrix clinopyroxene: $CaTs_{13.1\rightarrow10.7}Jd_{4.7\rightarrow3.7}XFe_{0.14\rightarrow0.12}$, $Al_{\sim0.3}$ (a.p.f.u); garnet hosted clinopyroxene inclusion: $CaTs_{14.1\rightarrow14.2}Jd_{4.8\rightarrow4.3}XFe_{0.14\rightarrow0.13,}$ $Al_{\sim0.3}$ (a.p.f.u).

Mineral phases pertaining to the secondary mineral assemblage have compositions of: amphibole: $XFe_{0.14–0.17}$, $Ba_{\sim0.0}Ti_{0.1–0.3}Cl_{\sim0.0}Si_{6.0–6.1}$ (a.p.f.u), spinel: $XFe_{0.24–0.30}$; $Al_{\sim2.0}Cr_{\sim0.0}$ (a.p.f.u).

An overview of the mineral assemblage of sample DS148A including composition maps showing the variability of the garnet compositions and elevated Na contents in the cores of clinopyroxene is shown in the Figure OM5.

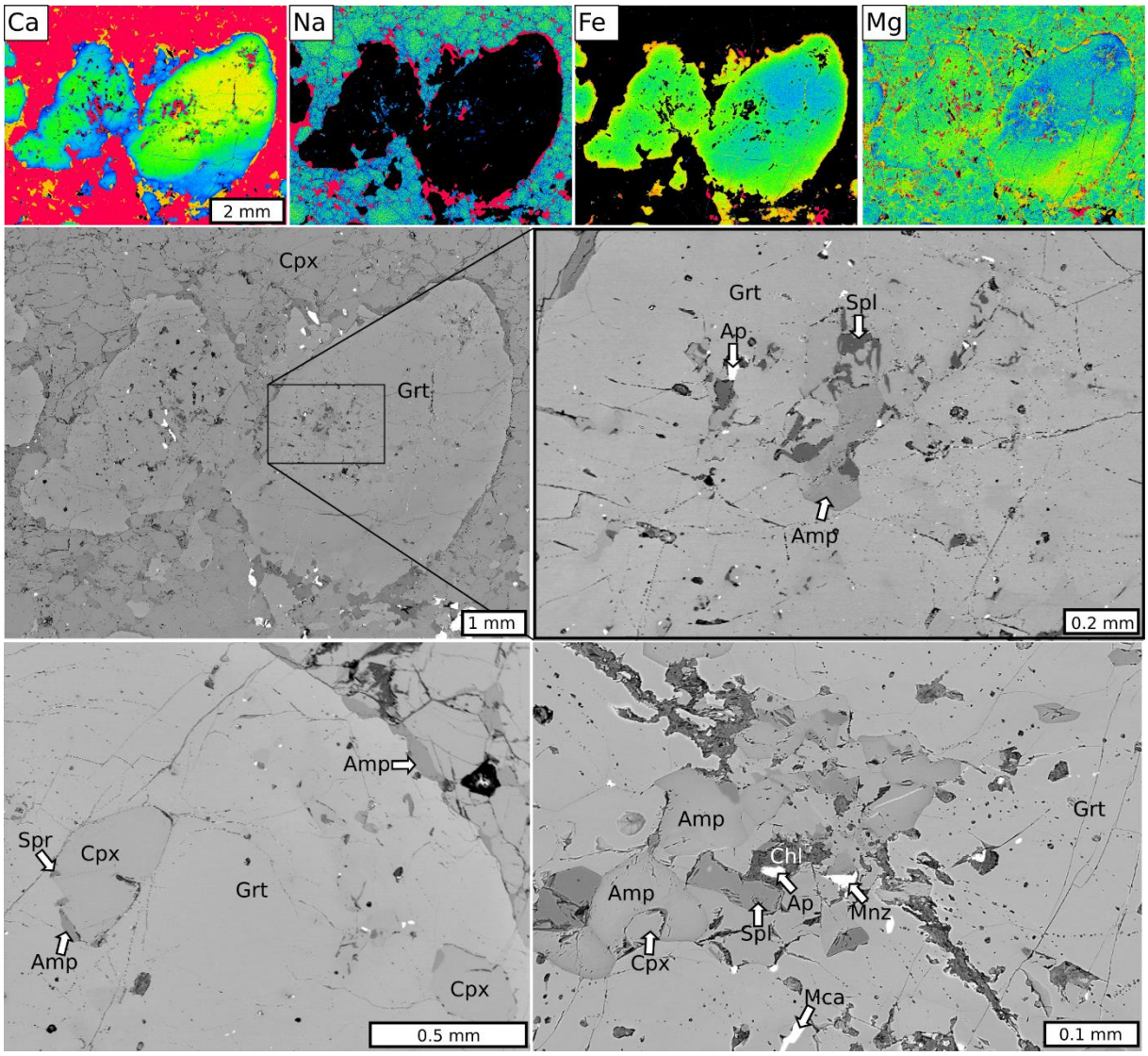

Figure OM5. Overview of mineral assemblage of garnet pyroxenite (sample DS148A) including composition maps of Ca, Na, Fe and Mg showing garnet compositional zoning and elevated Na-contents in matrix clinopyroxene.

DS148C – Garnet in this sample often forms elongated clusters with an average size of 2.5x3.4 mm where the individual garnet grains are up to 0.9 mm in size. Another form of garnet are individual elongated grains in the matrix, which are up to 1.6 mm large. Garnet occasionally hosts automorphic inclusions of clinopyroxene. The surrounding fine-grained matrix is dominantly formed by clinopyroxene with orthopyroxene exsolution lamellae. The matrix is further formed by subordinate orthopyroxene and amphibole. The sample is crosscut by several approximately 2 mm wide retrogressed zones, in which the primary mineral assemblage broke down into a fine-grained symplectite formed by orthopyroxene, clinopyroxene, sapphirine, spinel, plagioclase, and amphibole. These zones are also rich in Ba-rich mica, apatite, and ore minerals including nickeline, gersdorffite, and PGM-bearing phases.

The garnet clusters show a compositional plateau in Mg, Fe, and Mn in the central part, followed by a decrease in Mg and an increase in Fe and Mn towards the rim of the cluster: $Py_{71.7\rightarrow68.2}Alm_{14.6\rightarrow17.5}Sps_{0.4\rightarrow0.6}$, $XFe_{0.17\rightarrow0.20}$. On the contrary, individual garnet grains of the cluster show

slight decrease of the Ca content at their rims ($Grs_{14.1\rightarrow13.7}$). Individual garnet grains in the matrix show Mg and Ca depletion and Fe and Mn enrichment towards the rims: $Py_{70.4\rightarrow65.7}Alm_{14.6\rightarrow20.1}Grs_{14.5\rightarrow13.2}Sps_{0.4\rightarrow0.9}$, $XFe_{0.17\rightarrow0.23}$.

Clinopyroxene grains in the matrix do not show systematic zoning and their compositions are $CaTs_{6.8–8.9}Jd_{8.3–8.8}XFe_{\sim0.07}$, $Al_{0.2–0.3}$ (a.p.f.u). Clinopyroxene inclusions in garnet have compositions of $CaTs_{6.4–7.7}Jd_{8.5–9.2}XFe_{0.06–0.07}$, $Al_{\sim0.2}$ (a.p.f.u).

Mineral phases pertaining to the secondary mineral assemblage have the following compositions: clinopyroxene: $CaTs_{5.4–12.8}Jd_{2.2–9.8}XFe_{\sim0.07}$, $Al_{\sim0.3}$ (a.p.f.u), orthopyroxene: $XFe_{0.08–0.15}$, $Al_{\sim0.2–0.3}$ (a.p.f.u), plagioclase: $Ab_{3.7–5.2}$, amphibole: $XFe_{0.07–0.13}$, $Ba_{\sim0.0}Ti_{0.1–0.3}Cl_{0.0–01}Si_{6.0–6.2}$ (a.p.f.u), spinel: $XFe_{0.13–0.27}$; $Al_{1.9–2.0}Cr_{0.0–0.1}$ (a.p.f.u) and sapphirine: $XFe_{0.06–0.07}$.

An overview of the mineral assemblage of sample DS148C including composition maps showing the compositional zoning of garnet clusters is shown in the Figure OM6.

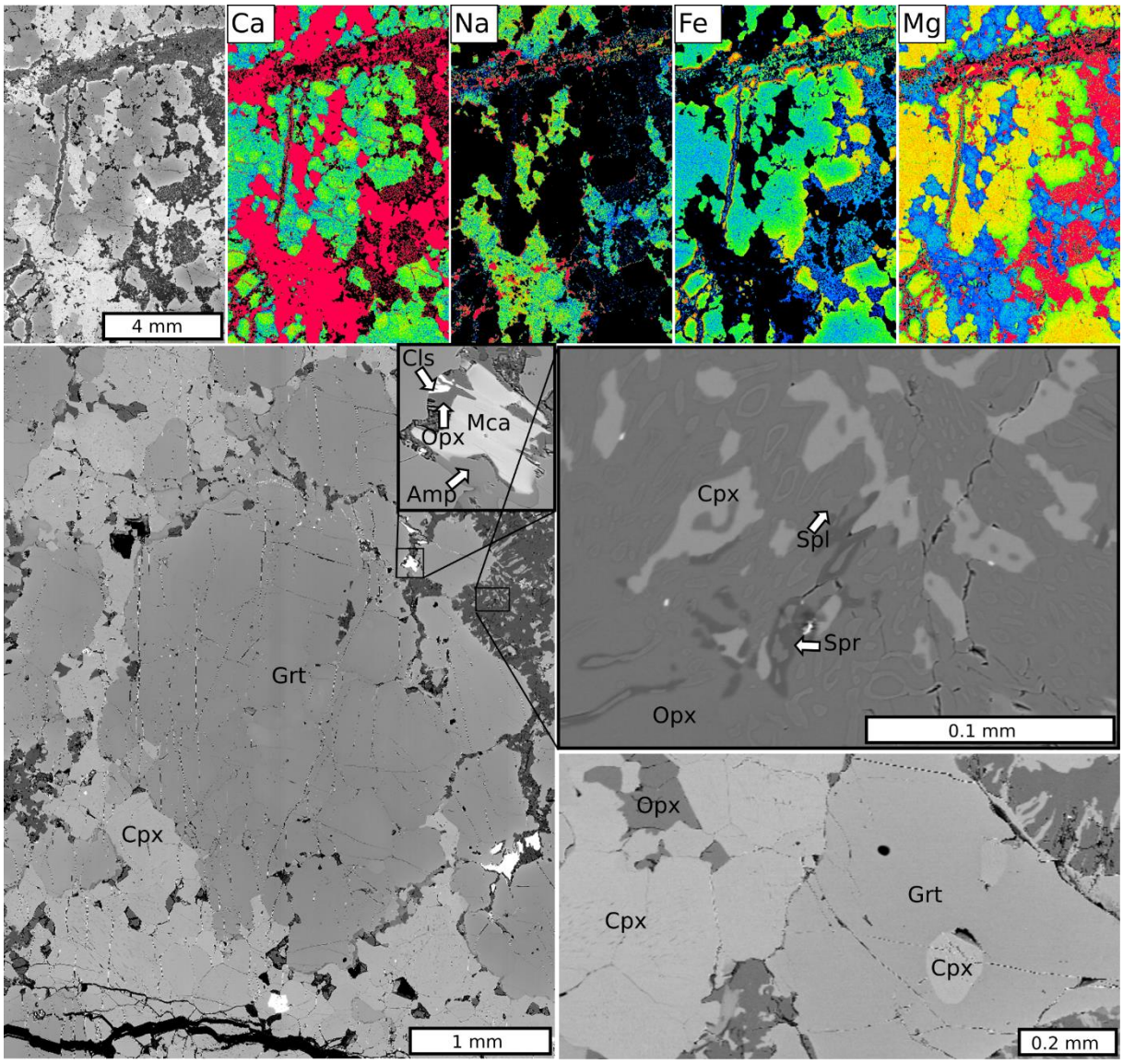

Figure OM6. Overview of the mineral assemblage of garnet pyroxenite (sample DS148C) including composition maps of Ca, Na, Fe, Mg showing the compositional zoning of garnet clusters.

St. Leonhard samples (SL1-X3, SL-PX-A, SL-PX-1-Y, SL-1B-I) – The Primary mineral assemblage is represented by up to 3 mm sized garnet porphyroblasts in a granoblastic matrix, which is predominantly comprised of up to 2.5 mm sized clinopyroxene with orthopyroxene exsolution lamellae, which are sometimes accompanied by amphibole. The primary mineral association is further formed by less abundant up to 0.8 mm sized orthopyroxene.

The matrix is further formed by coarse-grained amphibole and orthopyroxene. The average grain size in the matrix is about 0.4 mm. Garnet is often completely or partially surrounded by fine-grained by orthopyroxene, clinopyroxene, spinel symplectite.

The garnets are characterized by a compositional plateau in the central domain followed by a decrease of Mg and increase of Fe and Ca towards the rim: $Py_{70.1\rightarrow60.9}Alm_{17.9\rightarrow24.4}Grs_{11.3\rightarrow13.2}Sps_{0.7\rightarrow1.5}$, $XFe_{0.20\rightarrow0.29}$. Matrix clinopyroxene is characterized by a core to rim Na and Fe decrease and Mg and Ca increase:

$CaTs_{4.1\rightarrow5.7}Jd_{7.6\rightarrow5.6}XFe_{0.11\rightarrow0.07}$, $Al_{0.1–0.2}$ (a.p.f.u). The orthopyroxene exsolution lamellae in clinopyroxene have compositions of $XFe_{0.14–0.15}$, $Al_{\sim0.1}$ (a.p.f.u). Orthopyroxene: $XFe_{0.10–0.12}$, $Al_{0.1–0.2}$ (a.p.f.u).

Mineral phases pertaining to the secondary mineral association have compositions of: clinopyroxene: $CaTs_{\sim7.7}Jd_{\sim5.9}XFe_{\sim0.080}$, $Al_{\sim0.2}$ (a.p.f.u), orthopyroxene: $XFe_{0.08–0.12}$; $Al_{0.2}$ (a.p.f.u), amphibole: $XFe_{0.09–0.12}$, $Ba_{\sim0.0}Ti_{0.0–0.1}Cl_{0.0–0.1}Si_{6.0–6.3}$ (a.p.f.u), spinel: $XFe_{0.13–0.23}$; $Al_{1.9–2.0}Cr_{\sim0}$ (a.p.f.u).

An overview of the mineral assemblage of the samples from the St. Leonhard granulite massif including composition maps showing the compositional zoning of garnet is shown in the Figure OM7.

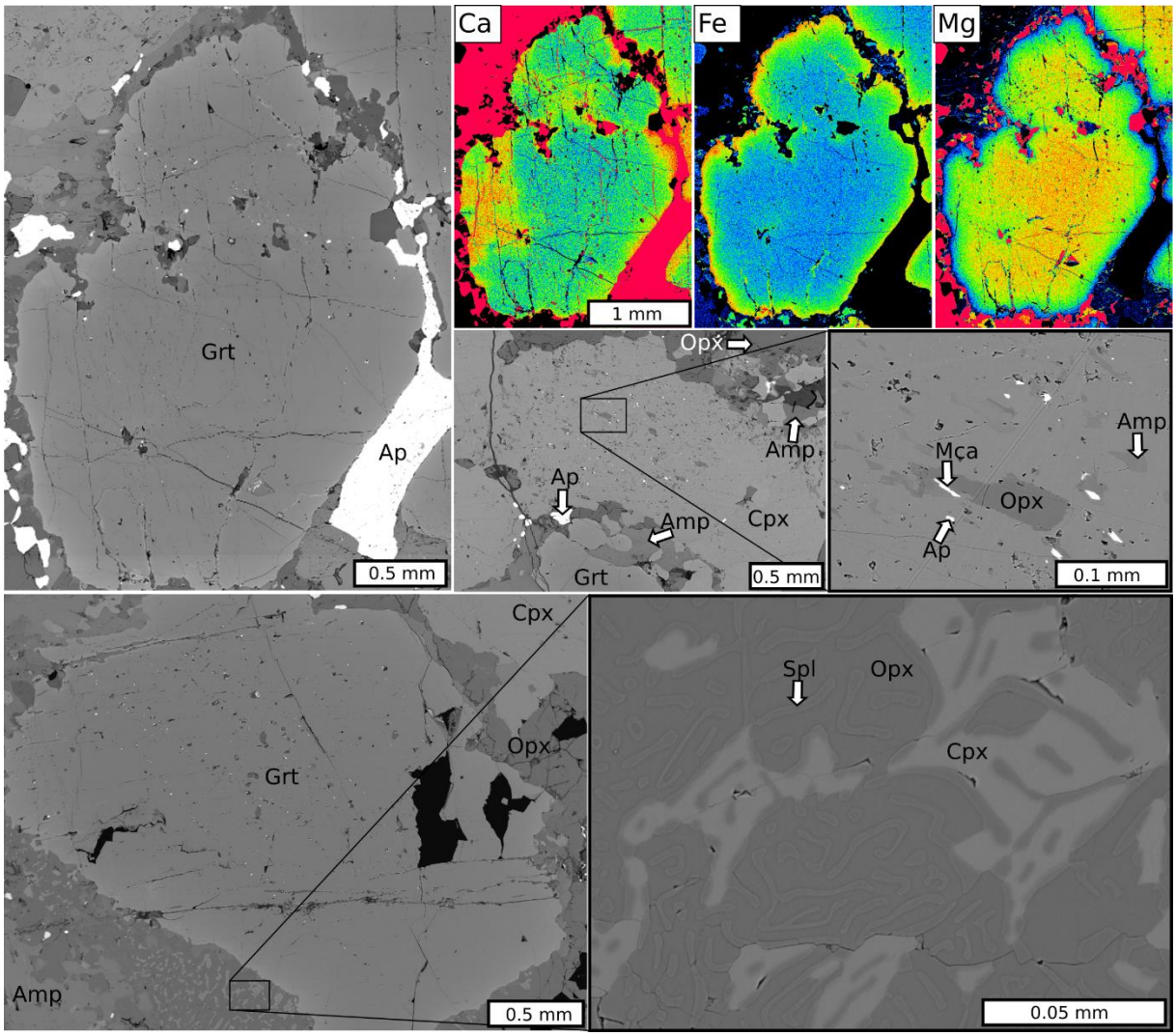

Figure OM7. Overview of the mineral assemblage of garnet pyroxenite from St. Leonhard including composition maps of Ca, Fe and Mg showing the compositional zoning of garnet.