S1 Detailed sample description

S1.1 FG1315

Mode: quartz ~ 50%, micas (2/3 phengite, 1/3 paragonite) ~30%, garnet ~15%, remaining ~5% epidote, chlorite, albite, rutile, graphite and zircon.

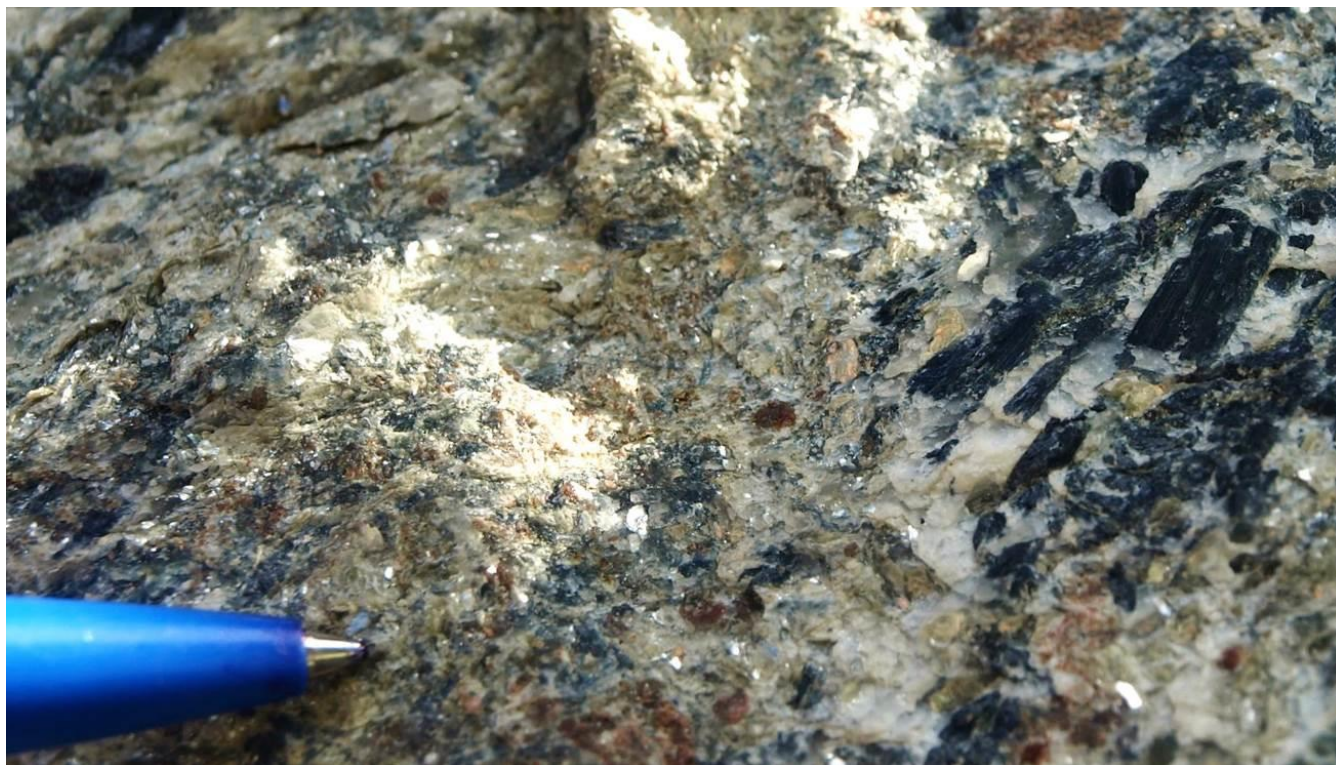
This quartz-rich garnet micaschist was sampled at Rechantier, Lys Valley (Valle d'Aosta, Italy, Fig. S1; X= 408514, Y= 5051580, ED 1950 UTM Zone 32N). It shows a pervasive foliation with thin quartz-rich bands and mica-rich layers. A stretching lineation marked by mica and quartz was well visible in the field and was confirmed by optical microscopy: quartz shows a crystallographic preferred orientation. Garnet grains are from some 100 µm to several mm in size (detailed description in the text). Allanite grains are elongate in the main foliation; they show a rim of clinozoisite up to 20 µm thick; rare relics of pre-Alpine monazite are preserved in the core. Locally, chlorite, albite and clinozoisite mark a minor greenschist retrogression. Rutile, graphite and zircons are present as accessory phases.

Figure S1: Outcrop of sample FG1315. The shiny aspect on the XY plane is due to white mica. The stretching lineation is marked by the alignment of white mica and quartz.

5 S1.2 FG12157

Mode: quartz ~ 40%, phengite ~30%, garnet ~15%, ~10% glaucophane + epidote, accessory chlorite, albite, rutile, zircon, titanite, ilmenite, and graphite.

This glaucophane garnet micaschist was collected at Lillianes, Lys Valley (Valle d'Aosta, Italy, Fig. S2; X= 409683, Y= 5054033). Its foliation (marked by phengite, glaucophane, and allanite) was deformed into open folds. Microscopically, 10 glaucophane shows two growth zones, with lighter cores and darker blue pleochroic rims due to higher Fe-content. Some crystals are also rimmed by green Ca-amphibole. Garnet is present as some millimetres crystals with an optically bright core

and dark rims, as well dark grains of ~100 µm size. Allanite shows a core and one or two rims, plus a border of clinozoisite, up to 20 µm thick. Chlorite, albite and green amphibole mark greenschist retrogression. Accessory phases are graphite, zircon, and rutile; the latter has a titanite overgrowth followed by an ilmenite rim.

5 **Figure S2: Outcrop photo of sample FG12157. Dark blue glaucophane, silvery phengite, is garnet, yellow epidote and white quartz.**

S1.3 FG1249

Mode: quartz ~ 40%, micas (2/3 phengite, 1/3 paragonite) ~40%, garnet ~15%, accessory epidote, chlorite, albite, rutile,
10 glaucophane, zircon, and opaques.

This garnet micaschist was sampled close to Faye, Lys Valley (Valle d'Aosta, Italy, Fig. S3; X= 406637, Y= 5053931). An intense foliation, marked by the preferred orientation of phengite, paragonite and allanite, wraps around garnet porphyrocrysts. Garnet has a grain size from some 100 µm to several mm. Two generations of allanite occur rimmed by epidote; pre-Alpine monazite is a rare relic in allanite cores. Sparse glaucophane is partly overgrown by albite and green
15 amphibole. Chlorite, albite, epidote and green amphibole also reflect minor greenschist retrogression. Rutile is elongate in the main foliation.

Figure S3: Outcrop of sample FG1249. Note that centimetre-size garnet is wrapped by the intense foliation marked by white mica.

S1.4 FG1347

Mode: quartz ~ 35%, micas (mostly phengite with minor paragonite) ~25%, chloritoid ~15% garnet ~15%, remaining ~10% epidote, chlorite, rutile, opaques, and zircon.

This garnet chloritoid micaschist was sampled close to Liévanere above Pont-Saint Martin (Val d'Aosta, Italy, Fig. S4; X= 406318, Y= 5052474). The main foliation is marked by phengite, paragonite, chloritoid, allanite and rutile; it wraps around large garnet porphyroblasts. In the field an intense stretching lineation is marked by chloritoid. Microscopically, chloritoid is

found in two generations, the younger of which is poikiloblastic and overgrows the main foliation. Garnet has a grain size from 100 μm to several mm in size (detailed description in the text). Some hundred microns pre-Alpine monazites are preserved and are partially overgrown by allanite and apatite symplectites. Allanite has frequent monazite relics in the core and is rimmed by clinozoisite. Chlorite grew at the expense of the garnet rim and along brittle fractures. Accessory phases are zircon and opaque minerals.

Figure S4: Outcrop photo of sample FG1347. The rusty red weathering colour is a typical feature of this lithotype. Chloritoid crystals up to 1 cm are grey in colour.

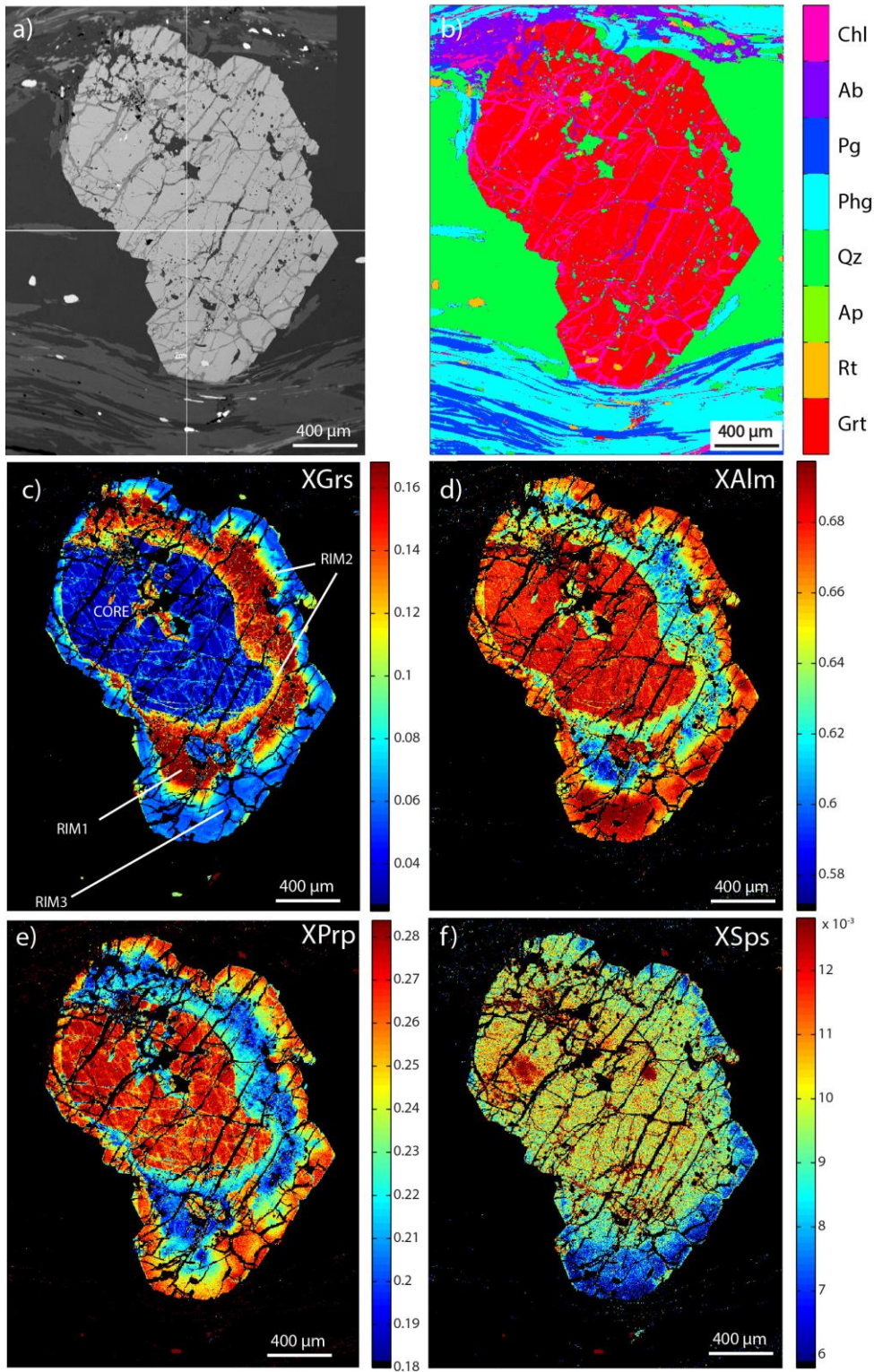



Figure S5: Large garnet (ø 1-2 mm) in sample FG1315. (a) BSE picture. (b) Mineral phases based on X-ray maps. Quartz inclusions are located inside Rim1 and between Rim1 and Rim3; rutile inclusions inside Rim3. Late fractures entirely dissect garnet and are filled by chlorite and albite. Garnet is located in a quartz rich band and is elongate perpendicular to the main foliation marked by phengite, paragonite and rutile. (c) Standardized X-ray map for X_{Grs} end-member. Note the lobate structure of the core, the pervasive fracture pattern sealed by garnet higher in X_{Grs} and the peninsula in which Rim1 and Rim2 grew. A fine network of veins is visible inside Rim1 and is sealed by Rim2. Rim3 produced two peninsulas inside Rim1 and Rim2. (d), (e) Standardized X ray maps for X_{Alm} and X_{Prp} show analogous features as in c. (f) Standardized X-ray map for X_{Sps}. Note two areas with higher X_{Sps}; the image is fuzzy because X_{Sps} values are low.

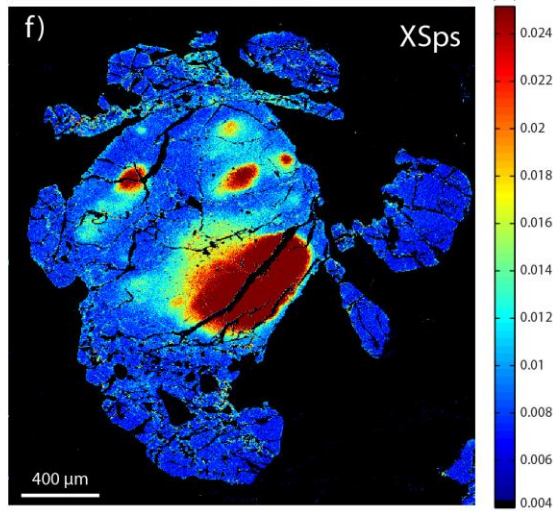
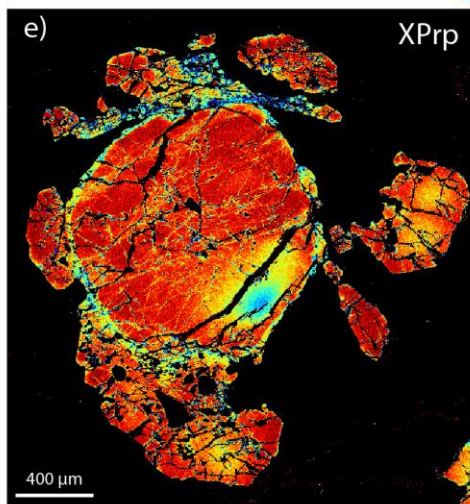
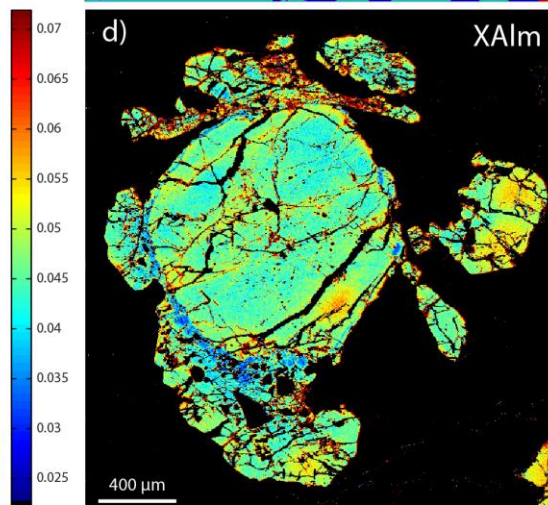
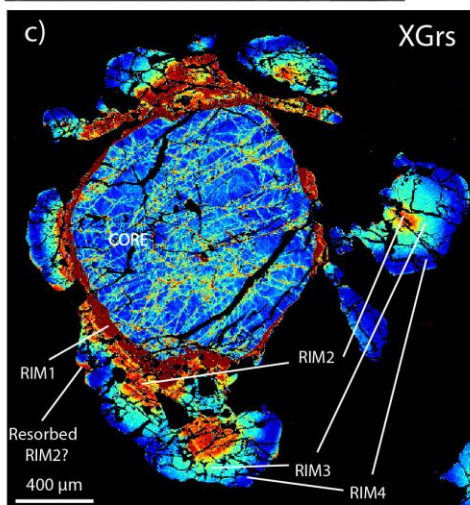
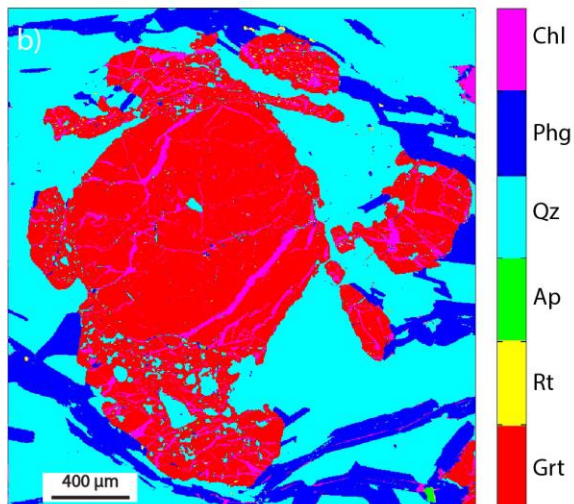
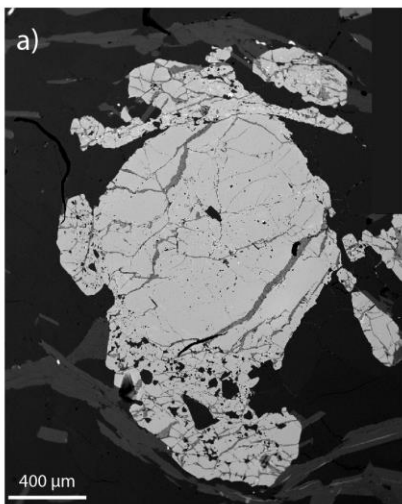



Figure S6: Asymmetric zoning in mm-sized garnet from sample FG1347. (a) BSE picture with a bright porphyroclastic core and a darker rim rich in quartz inclusions. **(b)** Mineral phases based on X-ray maps. Garnet is located in a quartz-rich band wrapped by phengite that defines the main foliation. Quartz inclusions are present inside the rims. Late fractures dissect all of the garnet generations and are filled by chlorite. **(c)** Standardized X-ray map for the X_{Grs} end-member. Note the fractured core sealed by garnet with higher grossular content. Satellite garnet shows the same zoning except that the porphyroclastic core is missing. **(d), (e)** and **(f)** X_{Alm}, X_{Prp} and X_{Sps} maps showing zoning in the core, a feature not visible in the X_{Grs} map.

MAJOR ELEMENTS	SiO2 wt-%	TiO2 wt-%	Al2O3 wt-%	Fe2O3 wt-%	MnO wt-%	MgO wt-%	CaO wt-%	Na2O wt-%	K2O wt-%	P2O5 wt-%	LOI wt-%	Cr2O3 wt-%	NiO wt-%	Sum wt-%
FG1315	64.09	0.95	17.12	7.78	0.08	2.34	0.72	1.05	3.13	0.10	2.06	0.01	0.01	99.43
FG12157	60.36	1.03	16.51	8.84	0.10	3.29	2.09	1.19	3.57	0.14	2.01	0.02	0.01	99.15
FG1249	58.82	1.03	18.87	9.58	0.23	2.76	1.60	0.88	3.94	0.13	1.58	0.02	0.01	99.44
FG1347	58.47	1.12	20.39	9.94	0.08	2.85	0.39	0.54	3.26	0.10	2.44	0.02	0.01	99.60

Table S1: Major element compositions of the studied samples