Additional file 3: Metamorphism of the Mte Plum rocks (Queyras nappe)

This additional file contains petrographic and mineralogical precisions about the rocks that form the Mte Plum klippe of the Queyras nappe.

Methods: Mineral chemistry

Mineral analyses were performed with a Cameca SX100 electron microprobe (Microsonde Ouest, Brest, France) operating in the wavelength dispersive mode. Operating conditions for spot analyses were set to 15 kV, 20 nA and 10 s counting time on the peak (spot size = 1 μm). The $\phi(\rho Z)$ matrix correction was applied based on Pouchou and Pichoir (1985). Standards were natural albite (Na, Si), orthoclase (K), corundum (Al), wollastonite (Ca), forsterite (Mg), $MnTiO_3$ (Mn, Ti), andradite (Fe), Cr_2O_3 (Cr), NiO (Ni).

Compositional layering in metabasites

In the layered metabasite sample GR 20 91 (see main article, Fig. 9 **g)**, one can distinguish the following domains:

The bluish layers are dominated by sodic amphiboles (strongly pleochroic) associated with a small amount of chlorite and quartz, and very small and dispersed grains of epidote. The main foliation is defined by the shape fabric of 'glaucophane'. A single crystal of a bright green mineral, positively identified as the copper carbonate malachite $Cu_2(OH_2)CO_3$, has been found in a bluish layer. Because it is moulded by the foliation, malachite remained stable at blueschist-facies conditions.

The greenish layers are essentially made of chlorite (X_{Mg} = 0.69-0.73), iron-rich epidote (X_{Ps} = 76-92 mole per cent) and nearly pure albite poikiloblasts, containing tiny crystals of blue amphibole. These inclusions are aligned parallel to the foliation outside the albite crystals. Also note the alignment of minute titanite crystals defining the foliation, overgrown by epidote and albite. This layer therefore records the transition from blueschist (syn-foliation) to greenschist (post-foliation) parageneses, with an early glaucophane – (lawsonite) – titanite assemblage, followed by the static growth of albite – epidote – chlorite. We assume that lawsonite was present rather than epidote during the early history because most if not all crystals of epidote are post-kinematic, overprinting the main foliation, and because lawsonite may have been the main repository of Ca in this layer. A narrow (1-3 mm thick) quartz vein is in contact with abundant blue amphiboles, sometimes overgrown by colorless to pale green amphiboles. Microprobe analyses confirm the glaucophane to actinolite transition. On one side of the quartz vein, a talc (X_{Mg} = 0.84-0.91; negligible Al and Na content) layer is present, containing long needles of actinolitic amphibole (Si= 7.89-8.01, X_{Mg} = 0.80-0.89), frequently with glaucophanitic cores. Actinolitic amphibole may also display radiating bundles across the foliation.

Composition of the sodic amphiboles from the metacherts and metabasites

Slight difference in composition can be noted between the amphiboles from the metachert and the blueschist (Fig. 1), consistent with the former being slightly paler than the latter.

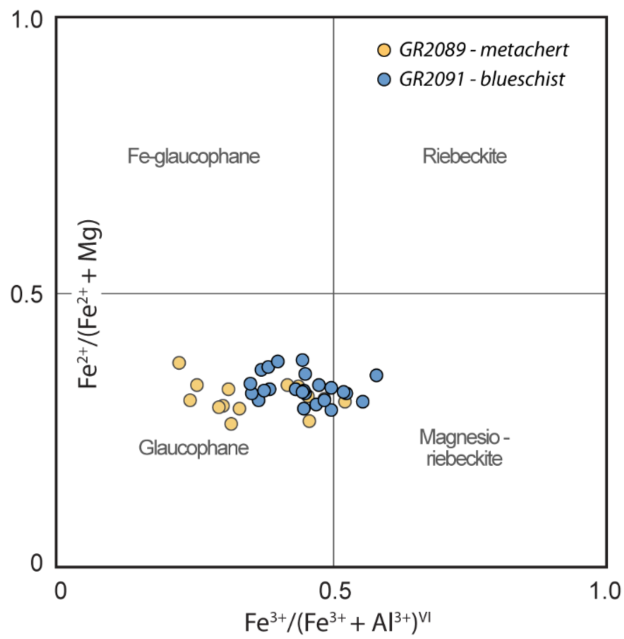

Fig. 1. Composition of the sodic amphiboles from two samples of the Monte Plum, plotted in a classification diagram. The structural formulae of the amphiboles have been recalculated using the procedure outlined by Schumacher in Leake et al. (1997) and are plotted here using the maximum estimation of the Fe3+ content.

References

Pouchou, J.L., & Pichoir, F. (1985). “PAP” ϕ(ρZ) procedure for improved quantitative microanalysis. In: Armstrong, J.T. (ed) *Microbeam Analysis.* San Francisco Press, San Francisco, CA, pp 104–106.

Leake, B.E., Woolley, A.R., Arps, C E.S., Birch, W.D., Gilbert, M.C., Grice, J.D,. & Guo, Y.Z. (1997). Nomenclature of amphiboles: report of the subcommittee on amphiboles of the International Mineralogical Association, commission on new minerals and mineral names. *American Mineralogist 82*, 1019–1037.

Mineral	Gln 47	Gln 48	Gln 52	Chl 44	Chl 45	Chl 46	Ab 56	Ep 59	Mu 60	Gln 8	Gln 12	Gln 22	Act 3	Act 4	Act 5	Tlc 77	Tlc 78	Tlc 79	Chl 16	Chl 17	Chl 18	Ep 20	Ep 21
Sample	GR 20 89	GR 20 89	GR 20 89	GR 20 89	GR 20 89	GR 20 89	GR 20 89	GR 20 89	GR 20 89	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91	GR 20 91
SiO_2	56.36	55.94	56.64	28.23	28.60	28.59	65.94	37.52	46.19	57.00	57.16	56.16	57.69	57.46	57.50	61.46	61.37	61.83	27.85	27.53	28.33	37.21	36.96
TiO_2	0.09	0.05	0.03	0.07	0.02	0.05	<0.01	0.17	0.07	0.07	<0.01	0.08	0.05	0.01	0.04	<0.01	<0.01	<0.01	0.01	0.13	0.05	0.14	0.09
Cr_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.03	<0.01	<0.01
Al_2O_3	6.46	6.14	8.05	19.90	19.80	19.51	18.90	23.75	31.17	7.50	7.44	6.45	0.73	0.68	0.65	0.00	0.02	0.08	19.01	19.22	19.03	22.91	23.62
FeO	15.75	16.00	13.13	14.29	14.44	15.07	0.05	11.12	2.23	14.26	14.73	15.64	7.26	7.11	7.12	7.89	8.35	4.92	16.48	15.33	15.74	12.38	11.33
MnO	0.09	0.10	0.13	0.12	0.12	0.16	0.02	0.08	0.04	0.07	0.03	0.04	0.08	0.10	0.13	0.01	0.08	0.05	0.30	0.13	0.26	0.09	0.04
MgO	10.33	10.30	10.50	23.88	24.17	23.42	0.02	<0.01	1.81	10.37	10.00	10.01	19.62	19.69	19.80	25.66	25.05	27.73	21.99	23.52	23.15	<0.01	<0.01
CaO	0.31	0.25	0.36	0.05	0.03	0.06	0.11	23.60	0.05	0.27	0.14	0.24	11.75	11.77	11.89	0.02	0.02	0.03	0.03	0.06	0.05	23.60	23.60
Na_2O	6.83	6.81	6.96	0.02	<0.01	0.01	11.38	<0.01	0.53	7.04	6.93	6.90	0.84	0.89	0.86	<0.01	0.03	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
K_2O	<0.01	0.02	0.00	<0.01	<0.01	<0.01	0.12	0.01	10.21	0.04	0.01	0.02	0.03	0.04	0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01
Total	96.21	95.60	95.81	86.57	87.19	86.90	96.55	97.60	92.29	96.59	97.15	95.55	98.07	97.74	98.01	95.03	94.96	94.65	85.68	86.02	86.68	97.72	96.91
Oxygen-equivalents	13	13	13	28	28	28	8	12.5	11	13	13	13	13	13	13	11	11	11	28	28	28	12.5	12.5
Si	7.96	7.95	7.96	5.67	5.70	5.74	3.22	2.99	3.19	7.97	7.98	7.99	8.00	7.98	7.97	4.03	4.04	4.02	5.73	5.61	5.73	2.98	2.97
Ti	0.01	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	1.08	1.03	1.33	4.71	4.65	4.62	2.33	2.23	2.54	1.24	1.19	1.08	0.12	0.11	0.11	0.00	0.00	0.01	4.61	4.62	4.54	2.16	2.24
Fe^{3+}	0.86	0.93	0.64	0.00	0.00	0.00	0.00	0.74	0.00	0.72	0.76	0.83	0.09	0.16	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.76
Fe^{2+}	1.00	0.98	0.90	2.40	2.41	2.53	0.14	0.00	0.13	0.95	1.01	1.03	0.75	0.67	0.64	0.43	0.46	0.27	2.83	2.61	2.66	0.00	0.00
Mn	0.00	0.01	0.00	0.02	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.03	0.05	0.01	0.00
Mg	2.17	2.18	2.20	7.15	7.18	7.01	0.24	0.00	0.19	2.16	2.10	2.12	4.05	4.08	4.09	2.51	2.46	2.69	6.74	7.15	6.98	0.00	0.00
Ca	0.05	0.04	0.05	0.01	0.01	0.01	0.00	2.02	0.00	0.04	0.02	0.04	1.75	1.75	1.77	0.00	0.00	0.00	0.01	0.01	0.01	2.03	2.03
Na	1.87	1.88	1.90	0.01	0.00	0.00	0.02	0.00	0.07	1.91	1.92	1.90	0.23	0.24	0.23	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.01	1.26	0.00	0.90	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Total	15.00	15.00	15.00	19.97	19.97	19.95	7.23	8.00	7.02	15.00	15.00	15.00	15.01	15.01	15.00	6.97	6.96	6.98	19.97	20.06	19.99	8.01	8.02
X_{Mg}	0.69	0.69	0.71	0.75	0.75	0.73	0.63		0.59	0.69	0.67	0.67	0.84	0.86	0.86	0.85	0.84	0.91	0.70	0.73	0.72		

Table 1: Representative mineral analyses for samples GR 20 89 and GR 20 91 from the Mte Plum rocks.