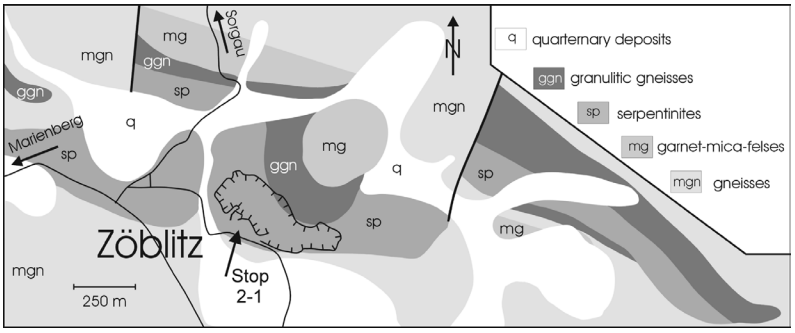
Stop 2-1 (Day 2). Garnet Peridotite at Zöblitz

Coordinates at the gate: N50°39′26.9″ E13°14′25.5″

Go on B171 from Marienberg to the east to reach the village of Rittersberg in a few kilometres and cross the river Schwarze Pockau. In Rittersberg, continue heading on B171 for the town of Zöblitz, which is reached after 1.5 km. In the town centre, just after passing the town church on the right hand side, turn to the left heading for the village of Sorgau. After 100 m turn into a small road (Angergasse, later Serpentinstrasse) to the right, go for ca. 600 m, and stop at the main gate to a large quarry (see Fig. 23), which is operated by Steinbruch Zöblitz GmbH (Tel. +49-37363-7256). The gate is on the left hand side; parking lots are on the right hand side of the road.



■ **Fig. 23.** Simplified geological map of the serpentinite body at the town of Zöblitz, GEU of the Saxonian Erzgebirge. This map is based on mapping by Hazard (1884).

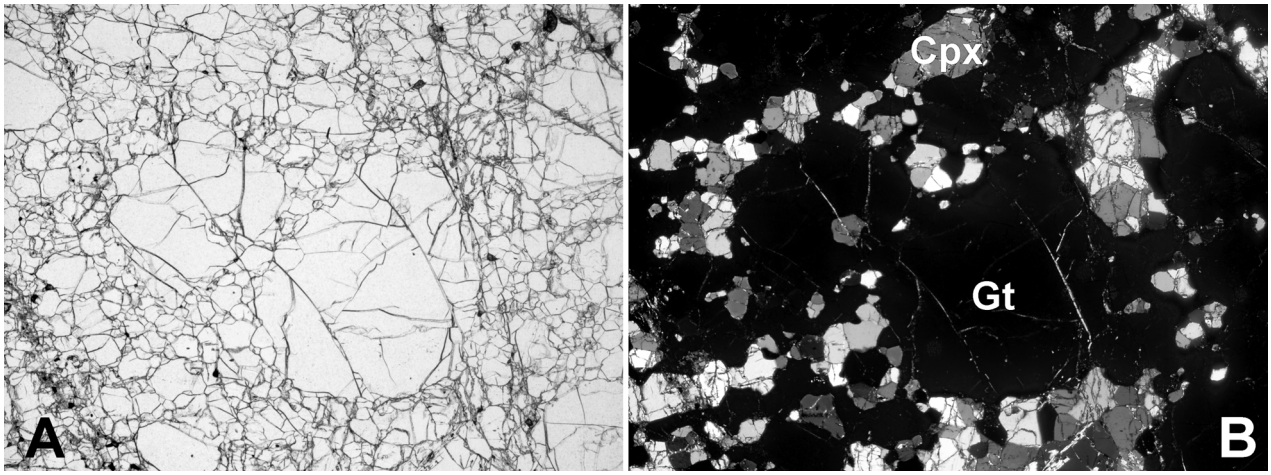
In past centuries serpentinite was quarried at Zöblitz as facing stone, for instance, in the interior of churches and palaces. In addition, drinking vessels and dinnerware were produced from the soft but tough serpentinite by turnery from the time of the late Renaissance. Today, the main purpose of the active quarry at the margin of Zöblitz is to produce macadam. Meanwhile, the serpentinite body at Zöblitz, which extends for ca. 3 km in an E-W direction (Fig. 23), is exploited near the town and for this reason, the quarry was extended to the east. Because of the active quarrying operations, it is uncertain as to which rock types will be visible in the active mining area. For this reason, two stops will be made in the old portion of the quarry near the margin of the serpentinite body. After passing through the gate turn to the left and walk to the low level of the quarry to reach the first stop. Close to the gravel dumps, there is relatively fresh garnet lherzolite in the quarry wall. The second stop will be on the opposite side of the quarry, where layers of garnet pyroxenite are exposed. This site is reached by walking to the NNE across the lower quarry level.

The serpentinite itself consists mainly of lizardite and subordinate clinochrysotile and antigorite. In addition, mm-size aggregates of chlorite occur, which are pseudomorphs after garnet. Occasionally, preserved portions of the original garnet lherzolite can be found as large remnant blocks in the old part of the quarry. The lherzolite consists of cm-size garnet with thin kelephitic rims in a matrix of mm-size equigranular olivine, clinopyroxene, orthopyroxene, and minor amphibole. The rock fabric is interpreted to be the result of recrystallization after deformation associated with exhumation.

Representative analyses of the minerals in the garnet lherzolite are given in Table 9. Garnet has chemically homogeneous cores and thin rims with slightly lower pyrope contents compared to the cores. Massonne and Bautsch (2004) assumed that the chemical composition of the matrix minerals and the garnet rim were in equilibrium and estimated P-T conditions of about 2.6 GPa and 1000 °C. Schmädicke and Evans (1997) estimated higher pressures up to 3.3 GPa at temperatures somewhat below 1000°C for the garnet peridotite at Zöblitz.

Pyroxenite layers within the peridotite body consist mainly of clinopyroxene and garnet and accessory rutile. Some pyroxenites contain up to cm-sized garnets that have been marginally transformed to smaller garnet crystals and equigranular clinopyroxene (Fig. 24). Garnet palaeocrysts and neocrysts are chemically zoned as shown in Figure 25. P-T conditions for garnet rims and matrix phases (Table 9; Massonne and Bautsch, 2004) are 1.66 GPa and 865 °C. Garnet core compositions gave much higher pressures of 3.9 GPa at 1100 °C (Massonne and Bautsch, 2004). Similar P-T conditions of 3.7 GPa and close to 1100 °C were reported by Massonne and Grosch (1995) for another garnet peridotite body situated about 10 km to the east of the serpentinite at Zöblitz. Another possible indication for such high pressures are abundant, tiny oriented ilmenite rods in the cores of some olivine grains in garnet lherzolite at Zöblitz (Massonne and Neuser, 2005). Although no quantifiable pressure significance can be assigned to these rods, a similar exsolution feature reported from the Alpe Arami peridotite massif in the central Alps has been cited as evidence for UHP conditions (Green et al., 1997). Summarizing the petrological information, the exhumation history of the Zöblitz ultrabasic body is similar to that for other ultrabasic rocks from the Saxonian Erzgebirge and the nearby Granulitgebirge (Fig. 1) as outlined by Massonne and Bautsch (2004).

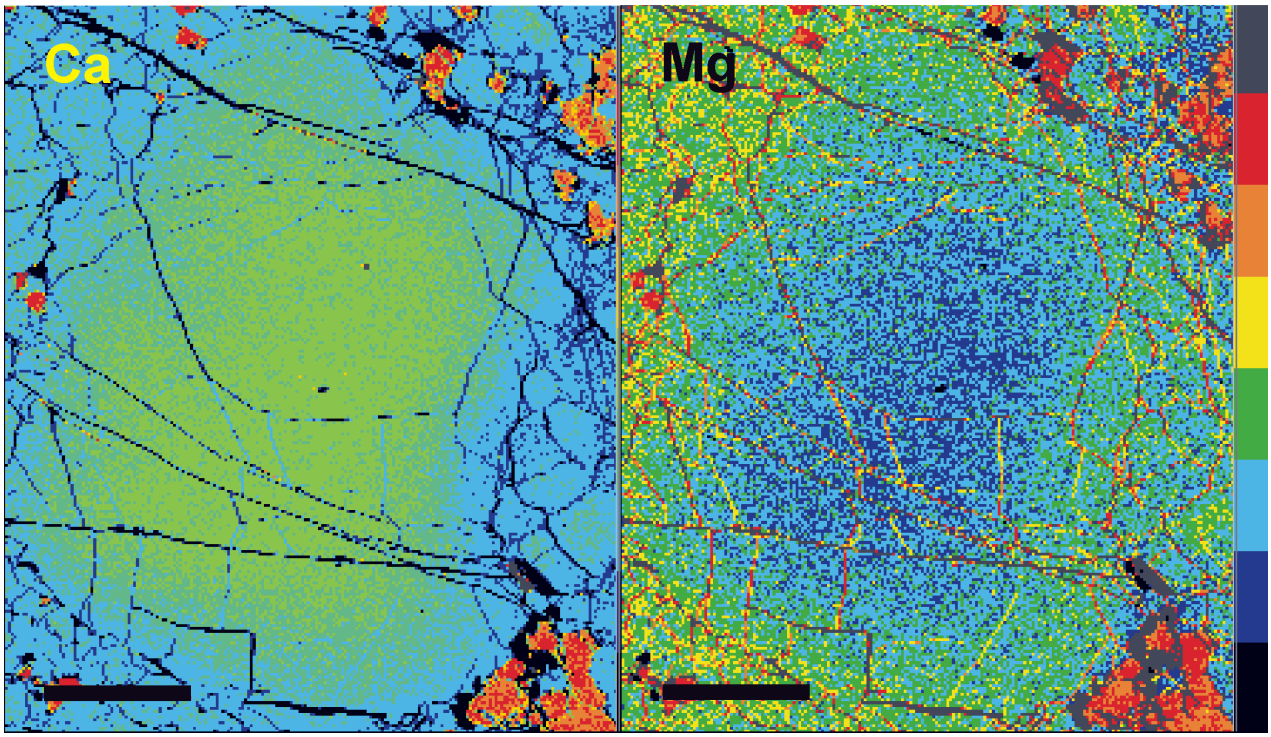
Garnet lherzolite from Zöblitz is slightly depleted in light REE (Table 10). Garnet pyroxenites vary significantly in composition (Table 10). Zircon grains separated from the Zöblitz garnet peridotite yielded U-Pb SHRIMP ages of 332 ±5(2σ) Ma (Liati and Gebauer, 2009). The inclusion mineralogy and the REE pattern of this zircon indicate a crustal origin. Liati and Gebauer (2009) concluded that during exhumation the Zöblitz



■ **Fig. 24.** Photomicrograph of garnet (Gt) in clinopyroxenite sample 18270 from stop 2-1 under plain polarized light (A) and crossed polarizers (B), taken from Massonne and Bautsch (2004). The matrix minerals probably recrystallized after deformation, associated with exhumation, but large garnet palaeocrysts remained. Image width is 4 mm. Cpx = clinopyroxene.

	Erz03-6d						18270			
	Garnet		Orthopyroxene	Clinopyroxene		Olivine	Garnet		Clinopyroxene	
	core	rim			rim		core	rim	core	rim
	1	6	15	20	36	40	14	140	35	136
SiO_2	42.31	42.26	57.90	54.77	54.39	40.91	39.91	40.35	53.64	51.10
TiO_2	0.66	0.63	0.14	0.41	0.44	0.02	0.57	0.25	0.48	1.03
Al_2O_3	21.92	21.83	0.98	3.72	3.47	0.00	21.97	22.72	5.45	8.61
V_2O_3	0.03	0.03	0.00	0.05	0.07	0.00	0.08	0.05	0.10	0.12
Cr_2O_3	1.60	1.67	0.14	0.92	0.85	0.00	0.01	0.05	0.32	0.04
FeO_{tot}	9.00	10.06	6.49	2.81	2.58	10.15	14.72	15.91	4.79	3.50
MnO	0.33	0.41	0.11	0.07	0.06	0.09	0.27	0.30	0.02	0.00
MgO	21.31	20.47	34.96	15.62	15.69	49.14	9.19	10.35	13.25	12.93
NiO	0.00	0.00	0.06	0.01	0.02	0.37	0.00	0.00	0.00	0.00
CaO	4.26	4.47	0.39	19.61	20.49	0.00	14.81	11.48	20.16	20.40
Na_2O	0.08	0.08	0.08	2.53	2.19		0.05	0.05	2.74	2.39
K_2O				0.01	0.00		0.00	0.00	0.01	0.01
Total	101.52	101.91	101.27	100.53	100.24	100.70	101.61	101.50	100.97	100.13
Si	5.925	5.928	3.941	3.918	3.908	0.9975	5.855	5.918	3.851	3.704
Al^{IV}			0.059	0.082	0.092				0.149	0.296
Ti	0.070	0.066	0.007	0.022	0.024	0.0003	0.063	0.028	0.026	0.056
Al^{VI}	3.618	3.609	0.020	0.231	0.202	0.0000	3.799	3.927	0.312	0.440
Cr	0.177	0.186	0.008	0.052	0.048	0.0001	0.001	0.006	0.018	0.002
V	0.003	0.004	0.000	0.003	0.004	0.0001	0.009	0.006	0.006	0.007
Fe^{3+}	0.202	0.202				0.0044	0.191	0.061		
Mg	4.447	4.000	3.547	1.665	1.680	1.7859	2.009	2.262	1.418	1.397
Mn	0.039	0.048	0.006	0.004	0.004	0.0019	0.033	0.038	0.001	0.000
Fe^{2+}	0.853	0.979	0.370	0.168	0.155	0.2027	1.616	1.891	0.288	0.212
Ni	0.000	0.000	0.004	0.001	0.001	0.0072	0.000	0.000	0.000	0.000
Ca	0.640	0.672	0.028	0.001	0.001	0.0000	2.328	1.804	1.550	1.584
Na	0.022	0.021	0.011	0.350	0.305		0.014	0.006	0.382	0.335
K				0.001	0.000		0.000	0.000	0.001	0.001

■ **Tab. 9.** Electron microprobe analyses (in wt.%) of minerals from serpentinized garnet lherzolite, Erz03-6d, and garnet-rich clinopyroxenite, 18270, of the serpentinite body at the town of Zöblitz (stop 2-1) taken from Massonne and Bautsch (2004). Structural formulae were calculated as follows: garnet: O = 12, six- and eightfold coordinated cations = 10; orthopyroxene and clinopyroxene: O = 12, Fe = Fe^{2+}; olivine: O = 4



■ **Fig. 25.** Concentration maps of Ca and Mg in garnet, marginally recrystallized to garnet + clinopyroxene, in sample 18270 from stop 2-1. The colour scale shows increasing element concentrations towards the top. Scale bars represent 500 μm.

	Garnet clinopyroxenite			Serpentinite
Sample	E2b	18270	E00-7B	E3b
SiO_2 in wt.%	46.17	40.70	42.20	39.26
TiO_2	0.45	1.00	1.30	0.08
Al_2O_3	14.76	18.10	17.88	2.04
FeO	8.11	12.51	12.64	7.04
CaO	9.16	12.40	13.60	0.68
MgO	17.72	10.70	8.26	37.96
MnO	0.21	0.23	0.21	0.11
K_2O	0.06	0.01	0.46	0.00
Na_2O	0.85	0.17	1.08	0.00
P_2O_5	0.02	0.04	0.08	0.00
H_2O_{tot}	1.41	1.52	1.37	11.63
CO_2	0.08	0.16	0.15	0.31
Sum	99.00	97.54	99.23	99.11
Li in ppm	*20.3*	*90.4*	*68.3*	*0.35*
Sc	*40.9*	*76.6*	*71.4*	*11.1*
V	220	402	465	51
Cr	683	112	261	2501
Ni	576	119	128	2350
Cu	*86.2*	*12.5*	*50.5*	*18.6*
Zn	21	80	92	50
Ga	*12.2*	*15.2*	*17.2*	*1.69*
Rb	*3.79*	*0.86*	*13.3*	*0.00*
Sr	*74.4*	*54.3*	*213*	*4.00*

	Garnet clinopyroxenite			Serpentinite
Sample	E2b	18270	E00-7B	E3b
Y	*13.1*	*22.7*	*25.8*	*1.77*
Zr	33	49	42	6
Nb	*0.43*	*17.5*	*1.42*	*0.02*
Sn	*0.39*	*2.88*	*1.14*	*0.00*
Ba	*15.6*	*12.3*	*118*	*2.58*
La	*1.40*	*3.95*	*1.44*	*0.18*
Ce	*4.54*	*10.27*	*5.63*	*0.55*
Pr	*0.77*	*1.77*	*1.38*	*0.10*
Nd	*3.71*	*11.07*	*10.20*	*0.49*
Sm	*1.11*	*5.59*	*4.84*	*0.18*
Eu	*0.46*	*1.53*	*1.38*	*0.06*
Gd	*1.53*	*6.13*	*4.65*	*0.24*
Tb	*0.33*	*0.74*	*0.66*	*0.05*
Dy	*2.31*	*3.98*	*4.69*	*0.31*
Ho	*0.54*	*0.80*	*0.91*	*0.07*
Er	*1.71*	*2.57*	*2.02*	*0.21*
Tm	*0.25*	*0.31*	*0.33*	*0.03*
Yb	*1.57*	*2.31*	*2.42*	*0.20*
Lu	*0.25*	*0.31*	*0.34*	*0.03*
Hf/Zr	*0.033*	*0.032*	*0.050*	*0.026*
Ta	*1.26*	*1.33*	*0.10*	*0.00*
Pb	*0.42*	*2.96*	*37.1*	*1.71*
Th	*0.29*	*1.23*	*0.00*	*0.00*
U	*0.06*	*0.72*	*0.16*	*0.03*

■ **Tab. 10.** XRF and ICP-MS (numbers in italics) analyses of ultrabasic rocks from the serpentinite body at Zöblitz, GEU of the Saxonian Erzgebirge, given by Massonne and Bautsch (2004).

ultrabasic body interacted with melts, which originated in the adjacent felsic gneisses. Perhaps the aforementioned delamination process, which involved crustal material and produced the saidenbachitic melts, could also be responsible for the crustal zircons found by Liati and Gebauer (2009) in the Zöblitz ultrabasic body.

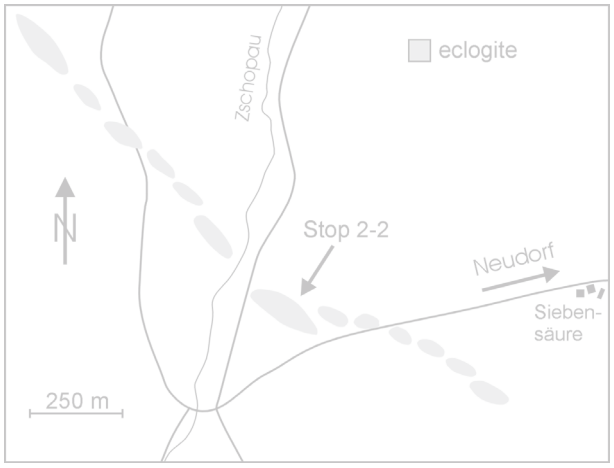
Stop 2-2 (Day 2). Eclogite at Siebensäure

Coordinates: N50°28′37.1″ E12°56′18.7″

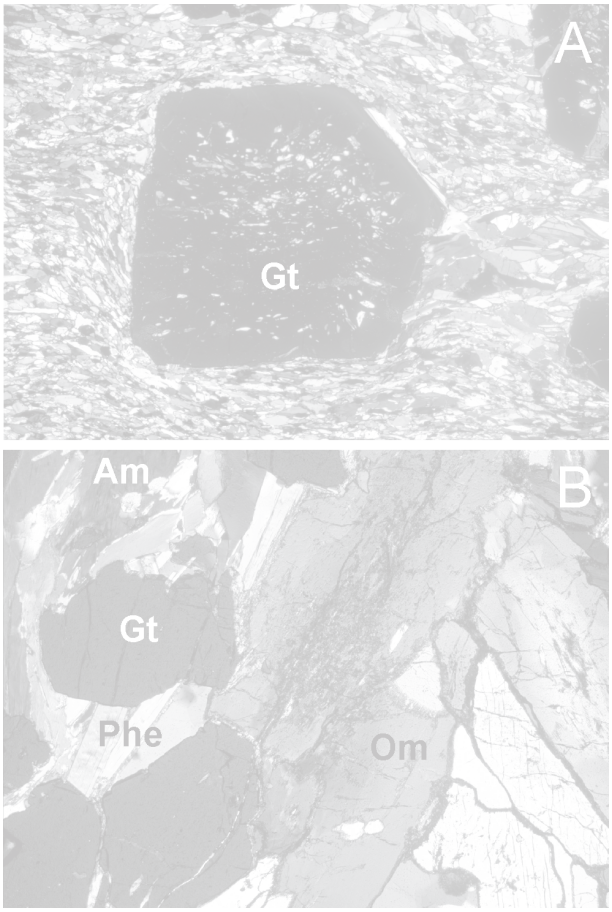
From the serpentinite quarry go back to Marienberg and continue via federal road B171 to the town of Wolkenstein to meet with federal road B101. Follow this road to the town of Annaberg-Buchholz. At the southern town exit leave B101 heading for the villages of Cranzahl and Neudorf. In the centre of Neudorf turn to the right into a small paved road, just before crossing the railroad tracks of the operating museum train, heading for the Forsthaus (forester's house) at the site Siebensäure. Pass the Forsthaus and stop on a parking lot for hikers. Walk for about 500 m in westerly direction and then move into the forest where cliffs expose eclogite and country rock (see Fig. 26).

The cliffs in the forest nearest to the road are orthogneisses, whereas those further north consist of eclogite, which is either a single, elongated lens or, as shown on the map (Fig. 26), a number of smaller lenses. These lenses are situated in the MEU only a few kilometres west of the boundary with the GEU (Fig. 2). The eclogite here is foliated and fine-grained. Strongly deformed portions contain mm-sized garnet embedded in a matrix of small oriented crystals, mainly of epidote and amphibole (Fig. 27A). In coarser-grained portions, cm-scale portions an earlier fabric is preserved, in which mm-sized garnet and omphacite occur with relatively large phengite grains (Fig. 27B). Epidote and amphibole are also present in the coarser-grained portions, where amphibole appears to replace omphacite.

Omphacite and garnet in the non-foliated rock portions of eclogite 18342 are strongly chemically zoned (Fig. 28, Table 11). The latter mineral, independent of its occurrence in deformed and non-deformed domains, shows prograde zoning with significantly decreasing Mn and increasing Mg contents from core to



■ **Fig. 26.** Simplified geological map showing the occurrence of eclogite bodies in an area of the MEU in the Saxonian Erzgebirge a few kilometres west of the village of Neudorf, which is located south of the town of Annaberg-Buchholz. These bodies are shown as mapped by Sauer (1884).



■ **Fig. 27.** Photomicrographs of eclogite sample 18342, taken from a cliff west of the forester's house at the Siebensäure site (stop 2-2). Image widths are 4 mm each. (A) Large garnet, seen under crossed polarizers, in a foliated matrix consisting mainly of amphibole and clinozoisite. The many inclusions in garnet are mainly quartz and rutile. (B) A preserved portion of palaeocrysts, especially of omphacite, under crossed polarizers. The dirty rims of omphacite are due to a late replacement by fine-grained symplectites of amphibole + plagioclase.