

Mohamed HAMDY^{1,2}, Thomas MEISEL³

**METASOMATOSIS IN THE UPPER MANTLE BENEATH THE SUDETES
(SW POLAND): MINERALOGICAL AND GEOCHEMICAL
CONSTRAINTS**

Ultramafic rocks associated with gneisses and amphibolites and occasionally with granitoids in the area of Sudetes (SW Poland) are interpreted as slices of subcontinental lithospheric mantle (SCLM). We here present data on these rocks that provide a base for study of the melting, depletion and metasomatic processes of SCLM. Peridotites from nine localities (from the area of the Orlica Śnieżnik Dome – OSD at Droszków village (DR) and on the slope of Haniak Mt. at Złoty Stok city (Z), as well as from the Sowie Mountains-SM at Bystrzyca Górna (BG), Zagórze Śląskie (ZŚ), Owiesno (OW), Potoczek (PO), Wiewiórka Mt. (WI), Chmielina Mt. (CH) and Niedźwiedź Mt. (NI)) were collected and studied petrographically, mineralogically and geochemically. Their mineral composition was analyzed using electron microprobe at Institute of Geological Sciences, Warsaw, Polish Academy of Sciences. Their whole chemical composition of major, trace and REE were analyzed using XRF and ICP-MS at General and Analytical Chemistry, University of Leoben.

Petrographically, the sampled rocks fall into three main groups. Group I consists of spinel harzburgites (at Z and NI) and rare spinel lherzolites (at NI), whereas group II comprises veined spinel harzburgites at ZŚ and CH and amphibole-bearing spinel serpentized harzburgites at BG, OW, PO and WI. Group III comprises phlogopite-bearing olivine pyroxene hornblendites at DR and Z and amphibole veins hosted in harzburgites at ZŚ and CH.

The spinel harzburgites at Z (ol–opx–cpx) with $Al_2O_3 = 0.64–0.94$ wt%, $mg = 0.91–0.92$, low HREE abundance reflecting strong depletion and fractional melting of SCLM, whereas harzburgites at NI ($mg = 0.89–0.90$) formed due to lower degree of melting of the spinel lherzolites. The spinel lherzolites that probably have interacted with a fluid/melt are enriched in Al_2O_3 (6.9–9.2 wt%), and depleted in MgO (30.3–32.3 wt%) compared to primitive upper mantle (PUM) composition as estimated by McDonough and Sun (1995). Harzburgites at NI display U-shaped

¹ *Institute of Geological Sciences, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland; e-mail:mhamdy@twarda.pan.pl*

² *on leave from Geology Department, Faculty of Science, Tanta University, 31111 Tanta, Egypt; e-mail:mhamdy@dec1.tanta.eun.eg*

³ *General and Analytical Chemistry, University of Leoben, Franz-Josef Straße 18, A-8700 Leoben; e-mail:Thomas.Meisel@notes.unileoben.ac.at*

REE distribution patterns ($La_N/Lu_N = 0.81-0.83$), moderately more enriched in incompatible elements especially LREE and Al_2O_3 (2.2-4.8 wt%) than harzburgites from Z. This enrichment might be caused by precipitation of disseminated amphiboles.

Although the veined spinel harzburgites at ZŚ and CH represent highly refractory rocks formed due to strong depletion in easily melted components having mg ranges from 0.90–0.91, $CaO = 0.09-0.7$ wt%, $Al_2O_3 = 0.46-1.19$ wt%, high contents of Cr reaching up to 5120 ppm and Fo contents reaching up to 0.96 and barren from hydrous minerals, they are strongly metasomatized (cryptic) with melt or fluids which later may have crystallise as amphibole veins. Rocks at CH are strongly enriched in LREE and MREE with distinctly high ratios of $La_N/Lu_N = 10$ in S-shaped pattern, whereas rocks at ZŚ have high ΣREE but with lower La_N/Lu_N ratio which sometimes equals ≈ 1 (semi flat REE pattern).

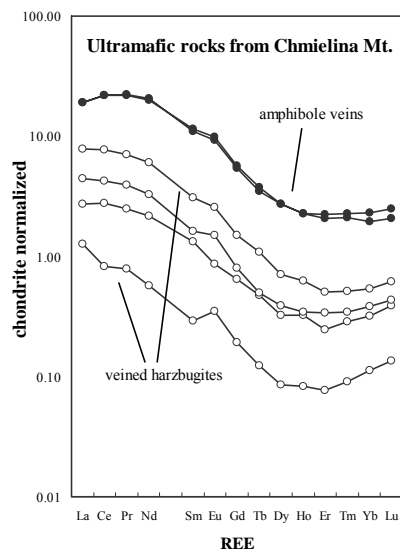
Compared with PUM composition the amphibole-bearing spinel serpentinized harzburgites at BG ($mg = 0.89-0.91$), WI ($mg = 0.88-0.92$) and OW ($mg = 0.93$) are characterized by LREE enrichment ($La_N/Nd_N = 1.2-1.4$ and $Er_N/Lu_N = 1.1-2.2$). This is not the case in rocks at PO ($mg = 0.90-0.92$), which are characterized by depleted REE composition (but $LREE/HREE > 1$). Usually, all these rocks have low CaO/Al_2O_3 , but in some samples the ratio is very high (Ca metasomatism).

Phlogopite-bearing olivine pyroxene hornblendites at DR and Z, belonging to group III, have mineralogical and geochemical characteristics reflecting metasomatic processes (modal and cryptic). They consist of coarse grained amphibole ($mg = 0.74-0.77$ in DR and $0.82-0.89$ in Z) poikilitically intergrown with grains of other minerals. Olivine has the composition of Fo_{64-69} in DR and Fo_{75} in Z. Orthopyroxene has the composition of bronzite in both DR and Z. Bronzite in Z has homogenous composition, but in DR it shows rimward increase of Al_2O_3 and TiO_2 contents. The majority of the clinopyroxenes are diopsides. The higher modal phlogopite abundance in DR is reflected in high concentrations of Rb and K (e.g. $0.82-1.07$ K_2O wt%).

Hornblendites from DR and Z are generally characterized by enrichment of REE concentration compared with PUM composition. REE concentration is higher in DR hornblendites than in those of Z. They display the same type of the REE distribution patterns, which have in common their La_N/Sm_N and $Gd_N/Lu_N > 1$ (2.5–2.9 in DR and 1.5 in Z) and (1.2 in DR and 1.1 in Z) respectively. However, in ZS hornblendites, have $La_N/Nd_N < 1$ (0.87, convex down pattern). Złoty Stok hornblendites show high whole-rock CaO/Al_2O_3 (6.7) relative to Z harzburgite residues (0.03–4.1), which is probably attributed to Ca metasomatism.

Amphiboles making up veins, cross-cutting harzburgites at ZŚ and CH, have higher mg (0.91–0.98 in ZŚ and from 0.96–0.99 at CH) and SiO_2 (46.8–57.6 wt%), but lower contents of Fe, Ti, Al, Cr, Na and K relatively to disseminated amphiboles either in hornblendites or in serpentinized amphibole-bearing harzburgites. Amphibole veins are characterized by REE enrichment that is lower than in the hornblendites at DR and ZS and higher than those of harzburgites containing disseminated amphiboles. REE concentration of amphibole veins display patterns

(S-shaped in CH and semi flat in ZŚ) similar to those of the harzburgitic host.



These chemical characteristics strongly suggest that amphibole in veins were formed from fluids or melts richer in MgO and SiO₂ and poorer in Fe, Ti, Al, Cr, Na and K relative to those forming disseminated amphiboles in both hornblendites and amphibole-bearing harzburgites. The fluids or melts must have been poorer in ΣREE than those forming hornblendites and richer in ΣREE than those formed amphibole-bearing harzburgites.

Using the above mentioned data of the ultramafic rocks it is suggested that the SCLM beneath Sudetes has suffered strong depletion followed by metasomatism: Both cryptic and modal metasomatism, sometimes accompanied by crystallization of amphibole veins. The metasomatism comprises

crystallization of poikilitic amphibole with less amounts of phlogopite (Z and DR), decreasing Mg-numbers, addition of highly incompatible trace elements, and increased whole-rock CaO/Al₂O₃ much greater than those of unmetasomatized rocks (Ca metasomatism). Chemical variations and the range in compositions observed among different localities imply that metasomatic agents of different compositions may have been in operation. The metasomatic agent affecting the harzburgitic host of the veined harzburgites (cryptic metasomatism) at ZŚ and CH was poorer in CaO and Al₂O₃ but richer in REE than the agent affected harzburgites at NI of group I (modal metasomatism represented by crystallization of disseminated amphiboles). On the other hand, metasomatic agents that affected the rocks at both Z and DR forming phlogopite-bearing hornblendites were richer in Fe, Ti, Al, Cr, Na, K and REE and poorer in Mg and Si than agents that metasomatized rocks in the other localities (probably fluids accompanied with granitoid intrusions at Z and DR). Partial melting and depletion of the SCLM beneath the Sudetes gave way to metasomatism as fluids or melts started to rise through the lithospheric mantle.

REFERENCES

McDONOUGH W., SUN S., 1995: The composition of the Earth. *Chem. Geol.*, vol. 120, 223-253.