EXTREMELY HETEROGENEOUS MUONG NONG TYPE MOLDAVITES. L. Švardalová[1], R. Skála[2], M. Trnka[3], S. Houzar[4], M. Novák[1]. [1]Department of Geological Sciences, Faculty of Sciences, Masaryk university, Kotlářská 2, 611 37 Brno, Czech Republic, e-mail: 78338@mail.muni.cz. [2]Institute of Geology, Academy of Sciences of the Czech Republic, Rozvojová 269, 165 00 Praha 6, Czech Republic. [3]Lithos Co. Ltd., Durďákova 41, 613 00 Brno, Czech Republic. [4]Department of Mineralogy and Petrography, The Moravian Muzeum, Zelný trh 6, 659 37 Brno, Czech Republic.

Introduction: Moldavites (the Central European tektites) represent natural glasses which belong to a group of similar materials from other regions (North American, Ivory Coast and Australasian) called tektites [1]. Recently, tektites have been generally interpreted as products of terrestrial impact events. Moldavites are believed to be formed by the Ries impact in southern Germany 14.3–14.8 Ma ago [2, 3]. They are deposited at distances of 200 km to 450 km from the source crater. Moldavites are found in southern Bohemia, southwestern Moravia, Cheb Basin (Czech Republic), in Waldviertel (Austria) and Lusatia (Germany). They were formed from sandy and clay Tertiary sediments that covered the surface of the Ries impact site [4, 5].

There are some regional variations in bulk chemical composition among moldavites. In the Bohemian area the composition is rather uniform, but some moldavites from northernmost Radomilice area are higher in SiO_2 and lower in all other major oxides. Moravian moldavites are higher in Al_2O_3 and FeO and lower in CaO than the average of Bohemian ones.

On the basis of their morphology, texture and chemical composition, tektites can be divided into two groups: (1) splash form and (2) Muong Nong type. The splash form tektites (SF) are relatively homogeneous. Muong Nong (MN) type tektites are layered, fragmental in shape and they do not display aerodynamic shapes), show wider heterogeneity in texture and chemistry, contain more bubbles, have higher contents of volatile elements and contain relic minerals [6]. All these differences are indicative of formation under lower temperatures than SF tektites. Wider chemical variability of MN type tektites may be interpreted as an incomplete mixing of several end-members of parent rocks [7]. The occurence of the MN type tektites among moldavites is still intensively debated.

Samples and methods: Nineteen samples of macroscopically heterogenous moldavites and four typical SF moldavites from three localities in southern Bohemia (Slávče near Trhové Sviny, Besednice, Dobrkovská Lhotka) were studied. Macroscopic and optical properties (optical microscope) of all specimens were studied. Chemical data of thirteen MN type moldavites and two SF moldavites was collected using a CAMECA SX100 microprobe. Accelerating voltage was 15 kV, sample current 15–20 nA, and electron beam diameter 5 µm. Following elements were analyzed (using the standards in brackets): Si (augite), Ti (titanite), Fe, Ca (andradite), Mn (rhodonite), Na, Al (albite), Mg (olivine), K (sanidine), Zr (zircon), Ba (benitoite), P (fluorapatite).

Macroscopic and microscopic characterization: The MN moldavites are usually darker in colour (brown, browngreen) in opposite of SF moldavites. With increasing heterogeneity they become less transparent. They display irregular fragment-like appearance. They show distinct layering or they have linear sculpturing. Some samples are bent. Sometimes needle-like bubbles were observed. Glass of two different texture – porous and compact – was identified to occur simultaneously in four samples.

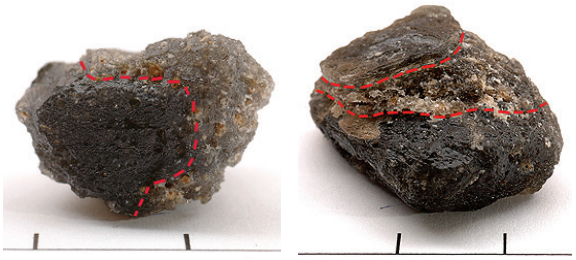

***Fig. 1**: Heterogenous MN type moldavites with porous and compact layers (1 division = 1 cm).*

The MN type moldavites are much more optically heterogeneous than the SF ones and much their fluidal structure is more pronounced. Alternating layers are almost parallel to each other in these moldavites or they are irregularly contorted. Parallel layering is locally highlighted by elongated inclusions of lechatelierite or bubbles. Bubbles and lechatelierite (of variable size and shape) are more frequent in MN type moldavites.

Chemical composition: The range of major element composition is significantly wider in MN type moldavites than in SF moldavites. This chemical heterogeneity is illustrated in *Table 1* where the data for MN and SF type moldavites are compared. Data comparison of compact (C) and porous (P) glasses of one sample of MN type moldavite shows that compact

layer is enriched in SiO_2, MgO and CaO and depleted in TiO_2, Al_2O_3, FeO, K_2O and Na_2O *(Table 1)*. Also, it should be noted that FeO, MgO and CaO content is extremely variable in MN type moldavites. We also found domains extremely rich in CaO (14.96 wt%), FeO (6.01 wt%), Al_2O_3 (16.99 wt%) and MgO (4.95 wt%), which were not detected among moldavites yet *(Table 2)*.

Table 1 *Average composition, minimum, maximum (wt%) and relative standard deviation (%) for SF moldavite (#21), some MN type moldavites (#1, #3, #7) and compact (C) and porous (P) glass of sample #10. Fe is total FeO.*

#		SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	K_2O	Na_2O
21	aver.	**79.65**	**0.30**	**9.77**	**1.60**	**1.95**	**2.37**	**3.50**	**0.41**
	min.	78.67	0.26	8.45	1.14	1.55	1.85	3.45	0.00
	max.	82.13	0.32	10.34	1.92	2.08	2.69	3.56	0.50
	r. s. d.	3.48	20.04	9.19	30.64	35.31	36.52	5.77	44.26
1	aver.	**81.24**	**0.26**	**9.82**	**1.49**	**1.15**	**1.30**	**3.85**	**0.45**
	min.	77.49	0.16	8.34	0.66	0.36	0.38	3.50	0.37
	max.	85.19	0.36	11.63	2.41	2.19	2.81	4.24	0.71
	r. s. d.	5.55	27.54	9.82	51.28	136.65	207.17	18.58	15.56
3	aver.	**78.08**	**0.25**	**10.06**	**1.59**	**2.48**	**3.83**	**3.22**	**0.29**
	min.	69.26	0.09	7.23	0.45	0.17	0.23	2.01	0.20
	max.	87.82	0.40	11.65	4.09	4.95	9.44	4.48	0.38
	r. s. d.	3.52	34.69	14.71	26.91	13.37	10.30	3.45	17.24
7	aver.	**80.74**	**0.33**	**10.49**	**1.76**	**0.84**	**0.80**	**3.74**	**0.06**
	min.	74.86	0.19	8.67	1.19	0.36	0.25	3.55	0.42
	max.	84.72	0.50	13.77	2.64	1.46	1.51	3.92	0.79
	r. s. d.	1.46	5.49	6.30	15.71	21.71	31.98	1.15	183.33
10/C	aver.	**80.06**	**0.33**	**10.73**	**2.00**	**1.11**	**1.35**	**3.69**	**0.53**
	min.	73.01	0.21	9.76	1.42	0.43	0.30	2.92	0.42
	max.	83.16	0.49	13.58	3.48	2.74	5.34	4.11	0.63
	r. s. d.	3.59	18.96	9.11	25.58	55.88	86.22	7.19	13.21
10/P	aver.	**79.20**	**0.44**	**12.16**	**2.79**	**0.69**	**0.26**	**3.78**	**0.55**
	min.	72.34	0.17	7.78	0.82	0.25	0.11	3.42	0.41
	max.	86.89	0.71	16.54	4.46	1.20	0.40	3.98	0.63
	r. s. d.	6.06	41.40	23.86	42.04	42.00	36.93	4.65	20.00

Table 2 *Selected compositional data for MN type moldavites (in wt%, extreme values in bold).*

Sample	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	K_2O	Na_2O	Total
4	63.64	0.46	11.45	3.70	3.53	**14.96**	1.20	0.24	99.42
2	66.35	0.73	15.69	**6.01**	2.75	5.07	2.72	0.61	100.11
2	71.02	0.77	**16.99**	4.49	1.20	0.80	3.80	0.72	99.90
3	74.91	0.23	9.65	1.40	**4.95**	6.17	2.15	0.20	100.02

Back-scattered-electron images (*Figure 2*) show the high chemical heterogeneity of the MN type moldavites. Apart from higher content of bubbles and inclusions of lechatelierite, also a substantial variability in chemical composition was observed.

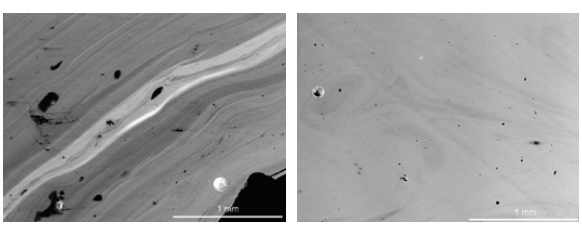

Fig. 2*: BSE images show the high chemical heterogeneity of MN type moldavite (left) and relatively homogenous SF moldavite (right).*

Figure 3 presents the results of analyses for two SF moldavites, a MN type moldavite with porous and compact parts and three other MN type moldavites. These values distinctly exceed so far recorded values for both south Bohemian and Moravian moldavites and therefore they extend further along both hyperbola arms of the plot in *Figure 3*. The porous layer is extremely enriched in FeO and TiO_2.

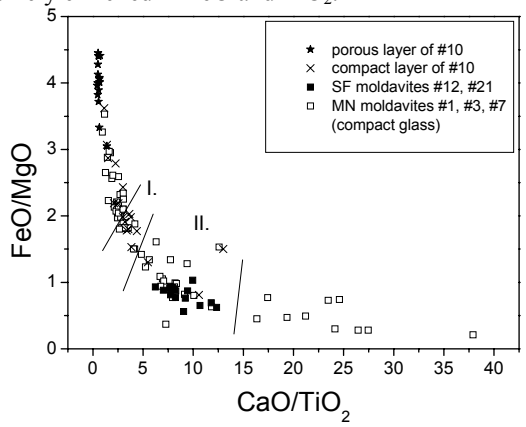

Fig. 3*: Plot of dependance FeO/MgO versus CaO/TiO_2 for studied samples (Sectors I. and II. represent typical ratios for Moravian (I.) and southern Bohemian (II.) moldavites after [8]).*

Conclusion: The MN moldavites are more heterogeneous than SF moldavites. They contain more bubbles, inclusions of lechatelierite and display substantial heterogeneity in chemical composition which exceeds the heterogeneity of all so far studied SF moldavites. Domains extremely rich in CaO, FeO, Al_2O_3 and MgO were found. In the MN moldavites, two distinct types of layers were identified – porous and compact. With respect to the distinct structure and chemical heterogeneity, studied samples are analogous to MN type indochinites.

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