

INVESTIGATION OF CHEMICAL DIFFERENTIATION OF PYROXENE DURING HIGH-TEMPERATURE PULSED LASER HEATING. I. BIMODAL COMPOSITION OF MELT. Yu.P. Dikov¹, M.V. Gerasimov², L.M. Mukhin², F. Wlotzka³. ¹IGEM, Acad. Science USSR, Moscow, USSR, ²Space Research Inst., Acad. Science USSR, Moscow, USSR. ³Max-Planck-Inst. f. Chemie, Mainz, F.R.Germany.

The investigation of silicate differentiation during rapid high-temperature heating is important for the understanding of natural processes such as hypervelocity impacts or explosions. Pyroxene is a significant type of silicate from cosmochemical and planetological considerations. So at the first step of our investigation we used clinopyroxene (augite) from mantle xenoliths; its chemical composition is given in column 1 of the Table.

As in our previous work [1-3], we used a powerful neodymium laser beam pulse focused (diameter 4 mm) on the flat surface of the pyroxene sample, which was placed in a closed cell filled with He at normal temperature and pressure. We made 9 experimental runs using laser pulses with ≈ 450 J luminous energy and $5 \times 10^5 - 10^7$ W/cm² energy density with a duration of 10^{-3} s. Under such conditions, the vaporization temperature is about 4000-5000 K [1]. A crater filled with boiling melt is formed. The melted layer was measured later on the crater walls to be about 0.1 to 0.2 mm thick. It contains multiple bubbles, which shows that the silicate vaporization proceeds as a bubble process, which provides good conditions for selective volatilization of elements into small vapor bubbles. A vapor cloud is formed from the released vapor bubbles. Small melted droplets are dispersed into this cloud and continue to loose volatiles from their surface. In the spreading cloud condensation occurred and after the laser pulse condensed particles filled the cell as a heavy smoke. The cell was flushed with He and at the outlet condensed particles and melted droplets were collected on a filter. The condensate formed a fluffy cohesive structure on the filter. Thus we had three types of material for study: residual melt on crater walls, melted droplets and condensed fluffy material (see [4]).

The melt and material from the crater walls were analyzed in polished sections with a Hitachi SEM, equipped with a Kevex energy dispersive x-ray analyzer. The droplets and fluffy material were analyzed in grain mounts using a TEM [4].

Investigation of the crater melt showed that its chemical composition differs from the initial pyroxene and has two distinct modes (Fig. 1): The first mode is similar to the initial pyroxene, but is noticeably enriched in Mg and slightly depleted in Fe (Table, column 3), and the second mode has the same level of enrichment in Mg, but is also enriched in Ca, Al, Ti and depleted in Na and Si (column 4). Droplets in general are more depleted in Na, Si and Fe compared to the crater melt (Fig. 2). While there is a wide range in chemical composition of droplets, it is possible to distinguish several groups with similar composition. Four such groups are presented in the Table, columns 5 to 8, positioned in order of decreasing silicon. It must be mentioned that the chemical composition of crater melt from column 3 is similar to that of droplets from column 5 and crater melt from column 4 similar to droplets from column 6. This argues for a genetic relation between the two modes of crater melts and droplets. As one can see from Fig. 2, the chemical composition of droplets is differentiated into two directions. The first one has differences in Mg concentration and the other one is enriched in Al, Ca and Ti. Compared to the crater melts, the Ca-Al-Ti rich droplets (columns 7, 8) are low in Mg.

The sequence of droplet groups from columns 5 to 8 in the Table has a steady tendency of depletion in volatile and semivolatile elements (Na, Si and Fe) and enrichment in refractory elements (Al, Ca, Ti). There were several low silicon droplets observed, which were composed for

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more than 50% of either CaO or Al₂O₃. Generally this sequence reflects a progressive mass loss of pyroxene melt due to selective vaporization. Investigation of a crater melt with depth within a crater shows that the Ca-Al rich melt forms the surface layer and the Mg-rich melt is situated below at the boundary with the initial pyroxene. This fact also supports the idea that the two modes of melt form through progressive stages of selective vaporization and differentiation of different parts of a melt. Fegley and Cameron [5] showed by thermodynamic calculations that a magma with solar abundances of elements during vaporization and progressive loss of mass first will be enriched in Mg due to loss of volatiles and then will become Ca-Al-Ti rich because of rapid depletion in Mg. In this way high-temperature impulsive processes which do not provide isothermal equilibrium vaporization of pyroxene can produce two different types of silicate melt: Mg rich and Ca-Al-Ti rich.

References: [1] M.V. Gerasimov et al., (1985) Vestnik Acad. Nauk USSR, No. 9, 10-25 (in Russian). [2] L.M. Mukhin et al. (1989) Nature 340, 46-48. [3] Yu.P. Dikov et al. (1989) LPSC-XX, 244-245. [4] Yu.P. Dikov et al. (1990) LPSC XXI, this volume. [5] B. Fegley and A.G.W. Cameron (1987) Earth Planet. Sci. Lett. 82, 207-222.

Table. Mean values for a certain amount of analyses among different groups of objects (wt%)

Column No	1	2	3	4	5	6	7	8
Object	Initial	Condensate	Crater melt	Crater melt	Droplets	Droplets	Droplets	Droplets
Number of analyses	18	10	25	23	6	10	17	7
Na ₂ O	2.75 ± 0.14	4.51 ± 0.28	2.59 ± 0.61	1.22 ± 0.15	1.28 ± 1.07	1.15 ± 1.00	1.28 ± 0.67	0.71 ± 0.62
MgO	13.09 ± 0.08	12.06 ± 0.69	15.10 ± 0.39	15.57 ± 0.57	14.79 ± 1.65	16.90 ± 1.05	7.89 ± 0.79	3.91 ± 0.99
Al ₂ O ₃	9.98 ± 0.09	7.57 ± 0.48	9.60 ± 0.78	15.07 ± 0.98	11.05 ± 0.37	17.56 ± 1.21	24.41 ± 1.80	31.39 ± 1.04
SiO ₂	49.29 ± 0.10	54.69 ± 0.90	49.14 ± 0.57	37.93 ± 1.08	50.05 ± 0.77	37.68 ± 1.79	34.16 ± 1.84	23.29 ± 0.73
CaO	15.46 ± 0.11	12.33 ± 1.28	14.95 ± 1.05	21.08 ± 0.63	15.13 ± 2.25	20.54 ± 3.25	26.94 ± 1.37	35.58 ± 2.66
TiO ₂	1.13 ± 0.03	0.74 ± 0.08	1.21 ± 0.06	1.96 ± 0.11	1.19 ± 0.22	1.73 ± 0.20	2.38 ± 0.19	3.38 ± 0.26
MnO	0.07 ± 0.02	< 0.1	0.12 ± 0.04	0.12 ± 0.06	0.13 ± 0.10	0.17 ± 0.14	0.10 ± 0.09	0.12 ± 0.09
FeO	8.22 ± 0.10	8.11 ± 0.36	7.14 ± 0.44	6.98 ± 0.55	6.28 ± 1.12	4.20 ± 0.52	2.63 ± 0.55	1.51 ± 0.18

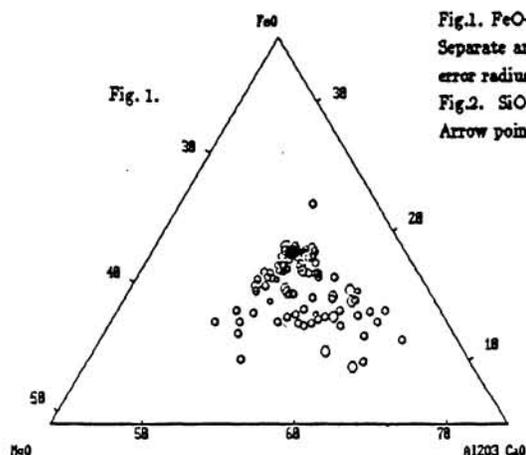


Fig.1. FeO-MgO-Al₂O₃ composition of crater melt. Separate analyses are given by circles with a 2 sigma error radius. Solid circle is initial pyroxene.

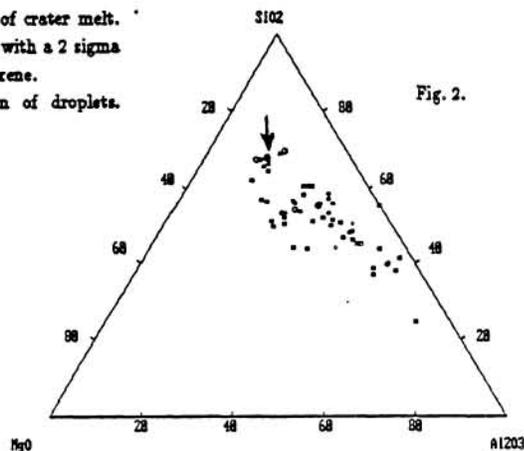


Fig.2. SiO₂-MgO-Al₂O₃ composition of droplets. Arrow points to initial pyroxene.