IRON VAPORIZATION AT HIGH-TEMPERATURE IMPULSE MELTING OF CHONDRITE-BASALT SYSTEM

Yakovlev O.I., Dikov Yu.P., Gerasimov, M.V.
yakovlev@geokhi.ru
dikov@igem.ru
mgerasim@mx.iki.rssi.ru

Financial support by RFBR, grant N 01-05-64564-a

Herald of the Earth Sciences Department RAS, № 1(20)′2002

URL: *http://www.scgis.ru/russian/cp1251/h_dgggms/1-2002/informbul-1.htm#planet-8.engl*

This experimental work is mainly dedicated to the iron vaporization from basic silicate melts that may be applied to the petrochemical problems of lunar glasses. It is known that the most part of glass particles in the lunar regolith is a result of melting caused by meteorite bombardment. The glass composition is varying in wide range that is explained by melting of different proportions of regolith components. Meanwhile there is a particular group of so-called mafic or pristine glasses (green and orange ones), which is thought to be of volcanic origin [1]. These glasses are thought to be important for lunar petrology, as their compositions, formed in lunar mantle, have inherited some features of primitive matter. However, there are not numerous publications proving usual impact origin for the mafic glasses [2,3]. To study possible chemical alterations of glasses during their short time of melt-droplet state as well as to test the well-known origin interpretations for impact or volcanic lunar glasses, we carried out some high temperature impulse melting experiments with rock and chondrite mixtures which modeled chemical relations between probable meteorite projectile and target lunar highland and mare rocks - anorthositic gabbro and Ti-basalt. Particular attention was spared to Mg/(Mg+Fe) ratios as their high meanings are character feature of the green and orange glasses.

The experiments were carried out in a pulse-laser setup in the regime of a free generation of laser radiation. The Nd glass laser had the following parameters: a wavelength of λ=1,06 μm, a pulse energy of 600 J, a power density of radiation of ~10^6-10^7 W/cm^2, and a pulse time of ~10^{-3}s. Typical temperature under such condition is 3000-4000 K. The experiments were performed in air at 1 atm. Laser beam was focused to a diameter of ~3 mm. It melted and vaporized a few tens of milligrams of the sample. A metal screen was installed in the path of silicate vapor and melt droplets at the distance ~7 cm from the sample. The glass spherules were found on the condensate matter. They were resulted from spraying of melt in a laser “crater”. High vapor pressure in the vaporization zone produced a flow out of the “crater”. This flow could transport some of the melted material from the wall of the cavity as tiny spherical particles (0.5-20 μm in diameter). The “life time” of droplets in melted state was not more 0.01 sec.

Two mixtures of rock and chondrite in mass proportion 1:1 were used. The first mixture composition simulated possible impact relation between chondrite projectile and highland target. It consisted of anorthositic gabbro and Murchison meteorite (C2). The total mixture composition was: Si 18.4; Ti 1.3; Al 7.7; Mg 9.4; Fe 14.8; Ca 6.9; O 41.5 (wt.%). The second mixture simulated impact melt relation of chondrite projectile and mare basalt. It consisted of Murchison and Ti basalt with total composition: Si 20.4; Ti 1.0; Al 4.4; Mg 8.8; Fe 21.0; Ca 3.5; O 40.9 (wt.%). Before experiments the mixtures was thoroughly ground up to ~1-3 μm particles. Chemical data of glass spherules were obtained with EDS microprobe analyses. The amount of analyzed spherules in the experiment with first mixture was 104, with second – 72. The results for Fe, Si, Mg, Ca, Ti, and Al were statistically analyzed and compared with the initial mixture components.

The morphology study of glass spherules showed that their surface contains often small globules of metallic Fe (fig. 1) with typical sizes ~10-100 Å. It is necessary to note the metallic Fe was practically absent in initial mixture that permits to think of Fe reduction process at high temperature impulse melting.

High saturation pressure of Fe^0 (at T~2800-3000^{o}C the pressure is about 1 atm) leads to fast vaporization and fast losses from silicate melt. The chemical analyses of spherules clearly confirm this. Two histograms (fig. 2,3) show the Fe content distributions in glass spherules as compared with initial mixture one. It is obvious that the Fe contents notably decreased in most spherules (in average ~2 times).

As the Mg volatility in high temperature silicate melts is low the Fe vaporization process causes to increases of Mg/(Mg+Fe) ratios. The histograms in fig. 4,5 show Mg/(Mg+Fe) ratio distributions in glass spherules as compared with initial mixture one. It is obvious that the ratios increase in spherules in average ~10% for experiments with anorthositic gabbro – Murchison mixture and in average ~25% for experiments with Ti-basalt – Murshison mixture.

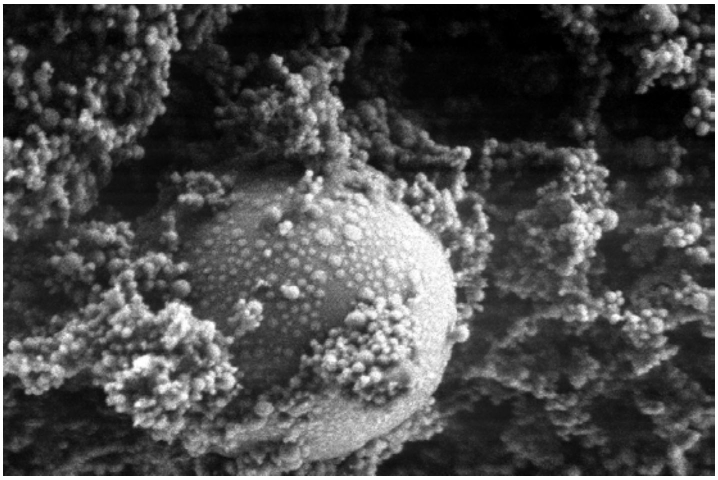

Fig. 1. Glass spherule (d≈1,5μ) with metallic Fe platelets on the surface

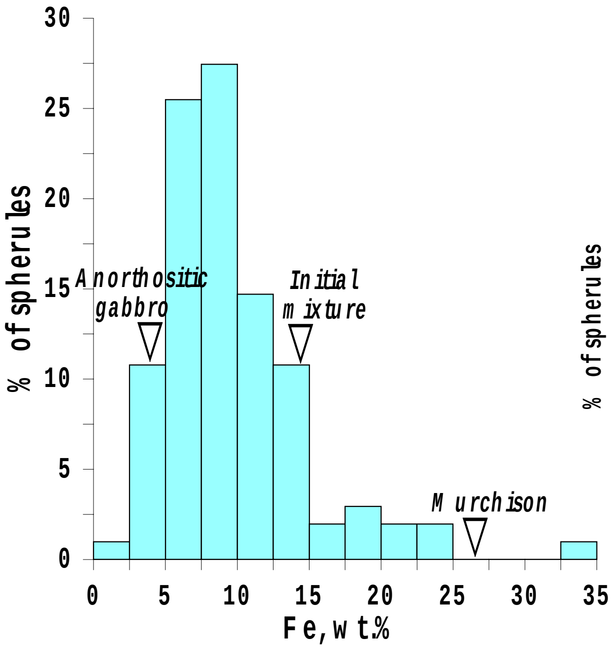

Fig. 2. Fe contents distribution in glass spherules

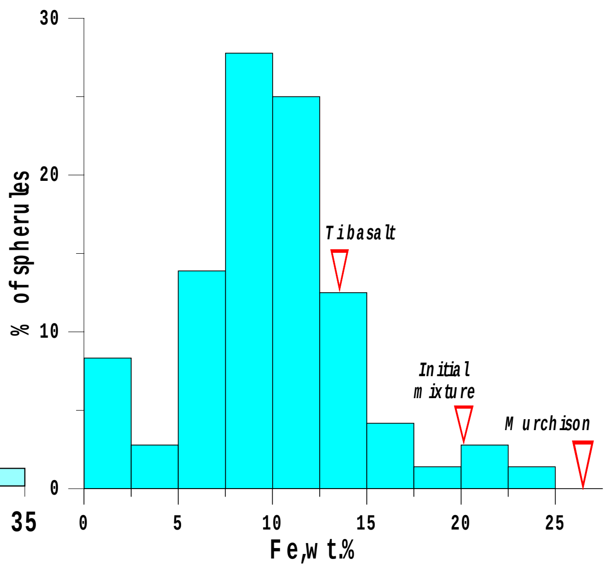

Fig. 3. Fe contents distribution in glass spherules

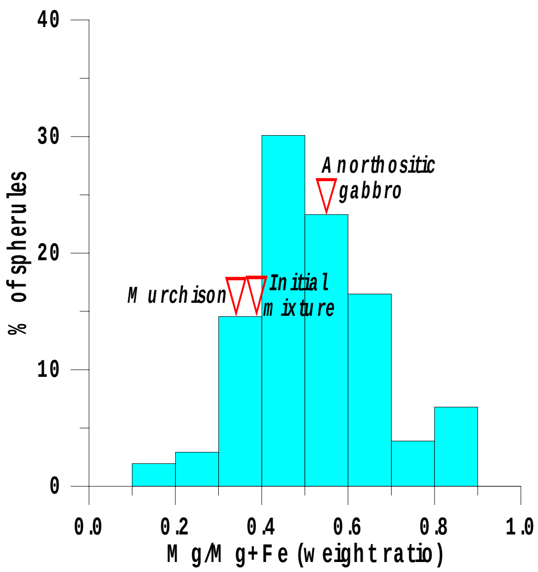

Fig.4. Mg/Mg+Fe distribution in glass spherules

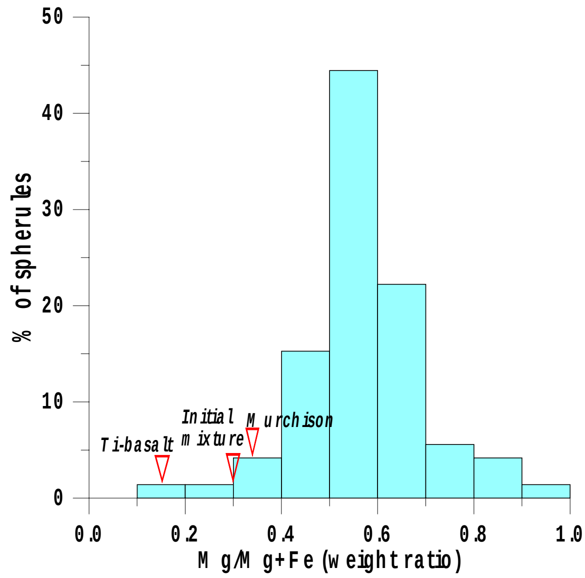

Fig.5. Mg/Mg+Fe distribution in glass spherules

These results permit to offer the alternative interpretation for high Mg/(Mg+Fe) ratio origin in lunar mafic glasses. In [1] there are comparative Mg/(Mg+Fe) data for green and orange glasses as well as for lunar mare basalts that show the lower average meanings (~10%) for the late. As the Mg/(Mg+Fe) is sensitive to the crystal/melt fractionation the many authors concluded less fractionation in the parent melt of mafic glasses. This important petrochemical property with another ones [1,4] permitted to construct the genetic model of magma melting in nondifferentiated Luna mantle that was source for green and orange glasses. However, our data show the high Mg/(Mg+Fe) ratio in glass spherules may be result of high temperature Fe reduction and vaporization. This process may guarantee the 10% and more increasing of Mg/(Mg+Fe) ratio in melt droplets. Thus the experimental data present the mechanism of impact origin of mafic glasses emphasizing possible role of Fe vaporization during high temperature melting process of chondrite projectile and lunar basalt targets.

References

1. *Delano J.W.* Pristin lunar glasses: criteria, data, and implications // Proc. Lunar Planet. Sci. Conf. 16th. 1986. In: JGR. V.91. № B4. P.D201-D213.
2. *Roedder E., Weiblen P.W.* Apollo 17 “Orange Soil” – a result of meteorite impact on liquid lava ? // Nature. 1973. V.244. №5413. P.210-212.
3. *Fudali R.F., Kreutzberger M., Kurat G., Brandstatter F.* Aspect of a glassy meteorite from the Moon bearing on some problems in extraterrestrial glass-making // J. Non-Crystalline Solids. 1984. V.67. P.383-396.
4. *Heiken G.H., McKay D.S., Brown R.N.* Lunar deposits of possible pyroclastic origin // Geochim. Cosmochim. Acta. 1974. V.38. P.1703-1718.