Abstract No. xiro110

The Mineralogy and Geochemistry of Los Angeles, a Martian Basaltic Meteorite

D. Xirouchakis (TSU and NASA JSC), A. Lanzirotti (CARS/Univ. of Chicago), D. Draper (TSU & NASA JSC), C. Agee (NASA JSC)

Beamline(s): X26A

Introduction: Los Angeles is the most differentiated of the shergottite-nakhlite-chassignite (SNC) group, but it also exhibits compositional and textural similarities to other basaltic Martian meteorites (e.g., Shergotty and QUE94201), and the lunar mare meteorite Asuka 881757 [1-6]. The texture of Los Angeles is that of microgabbro and it is dominated by relatively large (0.5-2.0 mm) anhedral to subhedral grains of pyroxene and generally subhedral to euhedral shocked plagioclase (maskelynite). Minor, late-stage phases of particular interest are, (i) subhedral titanomagnetite and ilmenite grains, (ii) olivine, (iii) olivine+pyroxene-dominated symplectites, (iv) pyrrhotite, (v) phosphate(s), and (vi) alkali-rich feldspathic glass closely associated with 50-100 Fm subhedral to euhedral SiO_2 grains [1-5, 7]. These late-stage textural features and phases seem to be common in Los Angeles, Shergotty, and QUE94201 [8, 9]. [1-5] previously argued that the symplectites consist of the assemblage hedenbergite+fayalite+silica, which they inferred to result from the breakdown of single-phase pyroxferroite, a pyroxenoid of $(Ca_{0.13-0.15}Mg_{0.02-0.00}Mn_{0.02-0.00}Fe_{0.83-0.85})SiO_3$ composition [11-13]. Implicit in the pyroxferroite breakdown model is the notion that the bulk of crystallization had to take place at $1.0 GPa and 950 EC [12, 14] with subsequent emplacement and slow cooling on or near the surface of the planet where single-phase pyroxferroite broke down to hedenbergite+fayalite+silica: $14Ca_{2/7}Fe_{12/7}Si_2O_6=4CaFeSi_2O_6+10Fe_2SiO_4+10SiO_2$. [8] considered the symplectites to be the breakdown product of a Ca-poor and Fe-rich pyroxene or pyroxenoid to Fe-rich olivine+augite+silica whereas [9] appear to favor the pyroxferroite breakdown model. An alternative reaction, that takes place throughout a range of pressure conditions, could have been the transformation of a pyroxenoid to pyroxene in the presence of already existing Fe-rich olivine and silica [12, 14]. But in the case of Los Angeles this requirement is not likely met. Nonetheless, a pyroxenoid breakdown model has to take into account the interplay between the magnesium content and temperature, and to a lesser extent pressure [12-15]. The breakdown reaction of a low-Ca pyroxene is perhaps a more viable mechanism provided that, (i) the symplectites have a pyroxene-like stoichiometry, (ii) the augite and olivine in the symplectites have the appropriate compositions and a silica phase is present, and (iii) the symplectites were not modified by the shock or by interaction with shock-related phases. Mass balance considerations also suggest that the breakdown of a low-Ca pyroxene or pyroxenoid produces significantly greater amounts of silica and Fe-rich olivine than augite. Thus, Fe-olivine and silica should dominate X-ray compositional maps or diffraction spectra of the symplectites. Although the crystal shape of the most euhedral SiO_2 grains in LA resembles that of tridymite and compositional data also suggest a low-pressure polymorph with sufficiently open structure to accommodate aluminum, alkalies, and other elements in trace quantities, the SiO_2 grains appear to be the loci of expansion cracks that propagate through the neighboring grains. Conceivably, shock pressure may have transformed the original SiO_2 phase into a high-pressure polymorph that expanded upon relaxation, possibly stishovite or a post-stishovite phase as it has been argued to have happened in Shergotty [16, 17]. The similarity between the SiO_2 grains in LA and Shergotty is intriguing and, considering among other things their similar within error crystallization and ejection ages, it hints to a possible genetic link.

Methods and Materials: In this study we concentrated on (1) the olivine+pyroxene-dominated symplectites, (2) the alkali- and silica-rich glasses, and (3) the SiO_2 grains. For that purpose we used the X26A beamline to collect XRD and XRF spectra of selected single phases and mineral assemblages.

Results: The presence of SiO_2 is equivocal in the olivine+pyroxene-dominated symplectites we studied. First, the XRD patterns of several symplectites do not contain peaks unique to either a low or high pressure SiO_2 polymorph. The peaks can be easily assigned to Fe-rich olivine and augite. Peaks characteristic of hedenbergite ($CaFeSi_2O_6$) are also absent. Second, many of the detailed Si X-ray maps of different symplectite areas in the samples suggest complete absence of silica or a silica-rich phase. But also others suggest that a phase enriched in silica, relative to olivine and augite, or perhaps silica is probably present. Conceivably, the symplectites may have been affected by the alkali- and silica-rich glass produced by the impact event (see below) and/or the shocked plagioclase. Because, we observe vermicular intergrowths of olivine+glass, olivine+augite±glass, and olivine+maskelynite. The alkali-and silica-rich phase in Los Angeles is inferred to have been liquid/glass because it does not appear to have a mineral stoichiometry. Although XRD of a 10x14 mm spot within a 200 µm area suggests a mostly amorphous material with weak feldspar and no silica polymorph peaks, the compositional data suggest that these glasses are a mixture of an alkali- (Na, K, Rb) and a silica-rich phase(s) with contributions from the adjacent shocked silicate and oxide minerals. This conclusion is consistent with the positive Eu anomaly observed in these glasses by [18]. These glasses also have a Br content of 19.5±2.5 ppm that is identical to the estimated average Br content of ~20 ppm of the Martian surface [19]. We preclude Br contamination of the samples during preparation; moreover, Br analyses of an adjacent shocked feldspar grain are clearly different (0.8 ppm). Therefore, we conclude that these glasses may be an impact shock-produced feature. Nevertheless, it is unclear whether the alkali-rich phase was originally, (i) an alkali-rich silicate glass, (ii) an alkali-rich feldspar, or (iii) alkali-rich plagioclase feldspar rims. [10] observed similar features in their study of Shergotty and Zagami, and they concluded that they may represent shocked mixtures of alkali-feldspars and silica.

Acknowledgments: This study was supported by NASA grants NCC 980 and 344-31-20-25. National Synchrotron Light Source (NSLS) is supported by the U.S. Department of Energy, Division of Materials Sciences and Division of Chemical Sciences.

References:

[1] Rubin, A.E., Warren, P.H., Greenwood, J.P., Verish, R.S., Leshin, L.A., Hervig, R.L. (2000a). Los Angeles: The most differentiated basaltic martian meteorite. Geology, **28**, 11, 1011-1014.

[2] Rubin, A.E., Warren, P.H., Greenwood, J.P., Verish, R.S., Leshin, L.A., Hervig, R.L. (2000b) Petrology of Los Angeles: A new basaltic shergottite find. 31st Lunar Planetary Science Conference, #1963 (abstract), Lunar Planetary Institute, Houston, USA.

[3] Warren, P.H., Greenwood, J.P., Richardson, J.W., and Rubin, A.E. (2000a) Geochemistry of Los Angeles, a ferroan, La- and Th-rich basalt from Mars. 31st Lunar Planetary Science Conference, #2001 (abstract), Lunar Planetary Institute, Houston, USA.

[4] Warren, P.H., Greenwood, J.P., and Rubin, A.E. (2000b) Los Angeles at Chicago. 63rd Annual Meteoritical Society Meeting, #5323 (abstr.).

[5] Greenwood, J.P., Warren, P.H., and Rubin, A.E. (2000) Late-stage crystallization of Los Angeles, a new basaltic shergotttite. 31st Lunar Planetary Science Conference, #2074 (abstract), Lunar Planetary Institute, Houston, USA.

[6] Mikouchi, T. (2000) Pyroxene and plagioclase in the Los Angeles Martian meteorite: Comparison with the Queen Alexandra Range 94201 Martian meteorite and Asuka 881757 Lunar meteorite. 63rd Annual Meteoritical Society Meeting, #5193 (abstr.).

[7] Xirouchakis, D., Draper, D.S., Schwandt, C.S., and Lanzirotti, A. (2001) Crystallization conditions of Los Angeles, a basaltic Martian meteorite. Geochimica et Cosmochimica Acta, (in press).

[8] Aramovich, C.J., Herd, C.D.K., and Papike, J.J. (2001) Possible causes for late-stage reaction textures associated with pyroxferroite and metastable pyroxenes in the basaltic Martian meteorites. 32nd Lunar Planetary Science Conference, #1103 (abstract), Lunar Planetary Institute, Houston, USA.

[9] Herd, C.D.K, Papike, J.J. and Brearley, A.J. (2001) Oxygen fugacity of the Martian basalts from electron microprobe oxygen and TEM-EELS analyses of iron-titanium oxides. American Mineralogist, **86**, 1015-10024.

[10] Stolper, E. McSween, H. Y. Jr. (1979) Petrology and origin of the shergottite meteorites. Geochimica Cosmochimica Acta, **43**, 1475-1498.

[11] Chao, E.C., Minkin, J.A., Frondel, C., Klein, C. Jr., Drake, J.C., Fuchs, L., Tani, B., Smith, J.V., Anderson, A.T., Moore, P.B., Zechman, G.R. Jr., Trail, R.J., Plant, A.G., Douglas, J.A.V., and Dence, M.R. (1970). Pyroxferroite, a new calcium-bearing iron silicate from Tranquillity Base. Proc. Apollo 11 Lunar Sci. Conf., Geochimica Cosmochimica Acta, *Suppl. 1*, **1**, 65-79.

[12] Lindsley, D.H. and Burnham, C.W. (1970) Pyroxferroite: Stability and X-ray Crystallography of Synthetic $Ca_{0.15}Fe_{0.85}SiO_3$ Pyroxenoid. Science, **168**, 364-367.

[13] Burnham, C.W., (1971) The crystal structure of pyroxferroite from Mare Tranquillitatis. Proceedings 2nd Lunar Science Conference, **1**, 47-57. Houston, USA.

[14] Lindsley, D. H., (1967) The join hedenbergite-ferrosilite at high pressures and temperatures. CIW., Year B., **65**, 230.

[15] Turnock, A.C. (1962) Preliminary results on melting relations of synthetic pyroxenes on the diopside-hedenbergite join. CIW Year Book, **61**, 81-82.

[16] El Goresy, A., Dubrovinsky, L., Sharp, T.G., Saxena, S., and Chen, M. (2000). A monoclinic post-stishovite polymorph of silica in the Shergotty meteorite. Science, **288**, 1631-1634.

[17] Sharp, T.G., El Goresy, A. Wopenka, B., and Chen, M. (1999) A Post-Stishovite SiO_2 Polymorph in the Meteorite Shergotty: Implications for Impact Events. Science, **284**, 1511-1513.

[18] Wadhwa, M., Crozaz, G., Lentz, R.C.F., and McSween, H.Y. (2001) Trace element microdistributions in Los Angeles: A new basaltic shergottite similar to, yet distinct from, the others. 32nd Lunar Planetary Science Conference, #1106 (abstract), Lunar Planetary Institute, Houston, USA.

[19] Rao, M.N., Bogard, D.D., Nyquist, L.E., McKay, D.S., and Masarik, J. (2001) Neutron Capture Isotopes in the Martian Regolith: Implications for Martian Atmospheric Noble Gases. Icarus, (in review).