PETROLOGY OF LOS ANGELES: A NEW BASALTIC SHERGOTTITE FIND. Alan E. Rubin[1], Paul H. Warren[1], James P. Greenwood[1], Robert S. Verish[2], Laurie A. Leshin[3,4] and Richard L. Hervig[3,5]. [1]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA (aerubin@ucla.edu); [2]P.O. Box 237, Sunland, CA 91040, USA; [3]Department of Geology, [4]Center for Meteorite Studies, [5]Center for Solid State Science, Arizona State University, Tempe, AZ 85287, USA.

Los Angeles is the fifth known basaltic shergottite, after Shergotty, Zagami, EETA79001 and QUE94201. It comprises two slightly-to-negligibly weathered stones (stone 1, 452.6 g; stone 2, 245.4 g) partially covered with fusion crust; they were found in October 1999 by RSV in his private rock collection. The name has been approved by the Nomenclature Committee of the Meteoritical Society.

Modal analysis (1052 points for stone 1; 1004 points for stone 2) indicates that Los Angeles consists of major maskelynitized plagioclase (47.9 vol.%, 43.6 vol.%) and pyroxene (40.7%, 37.7%), minor silica (3.2%, 4.9%), ulvöspinel (2.2%, 3.5%), fayalite (2.3%, 4.2%), K-rich feldspathic glass (1.2%, 2.4%) and merrillite (1.7%, 1.7%), accessory chlorapatite (0.1%, 1.0%), ilmenite (0.1%, 0.2%) and pyrrhotite (0.5%, 0.7%), and rare baddeleyite and hercynitic spinel. No grains of magnetite, magnesian olivine, or carbonate were identified.

Although some portions of Los Angeles exhibit an ophitic texture with small plagioclase grains (60×80 µm - 100×1300 µm) completely enclosed within larger (2×4 mm) Ca-pyroxene grains, most of the rock is subophitic with plagioclase laths ranging up to 1.4×7 mm and averaging ~0.5×2.5 mm, partly enclosed by 1.5-2.0-mm grains of Ca pyroxene. Stone 1 appears somewhat coarser grained than stone 2. Ca-pyroxene grains in Los Angeles are angular to somewhat irregular; in most cases their shape is controlled by adjacent laths of plagioclase. Back-scattered electron images of Los Angeles are included in an accompanying abstract [1].

Approximately 5-10 vol.% of the rock consists of ~50-200-µm-size patches of a fine-grained vermicular-to-microgranulitic intergrowth of fayalite, hedenbergite and silica that is presumed to be a breakdown product of pyroxferroite. This indicates that Los Angeles cooled from igneous temperatures (~1200°C) to 900°C within a period that was longer than about three days; more rapid cooling would have allowed metastable pyroxferroite to have survived [2]. Prior to its breakdown, the original pyroxferroite was polycrystalline; this is indicated by adjacent patches of the fayalite-hedenbergite-silica grains that vary in size (2-6 µm to 15-30 µm) and in orientation. In many cases, coarse grains of phosphate and ulvöspinel and small grains of pyrrhotite are adjacent to pyroxferroite; commonly, ~2-µm-thick fayalite rims occur at the boundary between pyroxferroite and ulvöspinel. In some cases, patches of K-rich feldspathic glass are associated with the phosphate-ulvöspinel-pyrrhotite-pyroxferroite regions. Within some merrillite grains there are ~50-µm-diameter pockets of late-stage K-Si-rich feldspathic melt similar to other mesostasis regions in the meteorite. Associated phases include hedenbergite, ulvöspinel, pyrrhotite and rare baddeleyite.

Ulvöspinel typically contains several patchy or lath-shaped grains of ilmenite. In some cases, elongated 2-µm-thick patches of fayalite occur within the ilmenite. Many ulvöspinel grains contain 15-100-µm-size grains of pyrrhotite. In several cases the pyrrhotite grains are elongated and aligned within the ulvöspinel host; the trails of pyrrhotite grains continue uninterrupted through ilmenite patches within the ulvöspinel.

Many grains of low-to-moderately calcic pyroxene (pigeonite to subcalcic augite) contain 0.7-4-µm-thick exsolution lamellae of more calcic pyroxene (augite). In some cases the lamellae are in two different crystallographic directions; in other cases where the orientation is nearly constant, the abundance of augite lamellae is nearly equal to that of the low-Ca pyroxene host grain. Many grains of augite and pigeonite contain exsolution lamellae of each other in their interior. Some exsolution lamellae are deformed as a result of shock or overburden pressure. Augite exsolution lamellae within pigeonite in Shergotty [3] and Zagami [4] are much smaller (~20-300 nm thick), indicating that these rocks cooled more rapidly than Los Angeles.

Like other shergottites, Los Angeles has been shocked. Maskelynite formed at a shock pressure ≥30 GPa [5]; other shock features include mosaic extinction and planar fractures in Ca pyroxene grains, pyrrhotite veins (0.5-3 µm thick, 15-150 µm long) within Ca pyroxene, polycrystallinity of some pyrrhotite grains and, in stone 1, a 350-µm-long fault within a 700×1200-µm-size Ca-pyroxene grain. Displacement along the fault averages ~15 µm. The fault cuts through hedenbergite, two patches of pyroxferroite, a large grain of merrillite (including a 2-µm-thick fayalite rim at the boundary with pyroxferroite) and a small lath of pyrrhotite + ulvöspinel. It is clear that this late-stage fault formed after the breakdown of pyroxferroite. A smaller fault with a 5-8-µm displacement occurs in a nearby ferropigeonite-hedenbergite grain.

Pyroxenes in Los Angeles are richer in FeO than those in Shergotty or QUE94201. The compositional trend of the pyroxene is qualitatively similar to that in QUE 94201 (but it starts out at more ferroan compositions); the pyroxene trend in Los Angeles is appreciably different than that in Shergotty. Los Angeles contains blocky augite and pigeonite, similar to those in Shergotty but different than the augite-rimmed pigeonite grains in QUE94201. In Los Angeles, magnesian augite and pigeonite cores are rimmed by ferropigeonite, which in turn grades into pyroxferroite. The FeO/MnO ratios of the pyroxenes (~35±10) are similar to those in other martian meteorites.

Maskelynitized plagioclase compositions are An56-38Ab43-56Or1-7, nearly identical to the range found in Shergotty [6]. The large laths exhibit normal zoning, suggesting that the plagioclase was not significantly altered in composition during maskelynitization.

Pyrrhotite in Los Angeles ($Fe_{0.98}S$; n=9) is less depleted in Fe than that in Shergotty ($Fe_{0.94}S$; [6]) or QUE94201 ($Fe_{0.92}S$; [7]). Ulvöspinel (0.06 wt.% MgO, 1.6% Al_2O_3, 0.60% MnO, 70.7% FeO, 0.08% Cr_2O_3, 0.06% CaO, 24.5% TiO_2; n=20) contains more FeO and less Al_2O_3, MnO and Cr_2O_3 than in Shergotty and QUE94201. Ilmenite (0.10% MgO, 0.61% MnO, 47.4% FeO, 0.04% Cr_2O_3, 51.7% TiO_2; n=4) has no hematite component and contains less MgO than in Shergotty and QUE94201.

The abundance of plagioclase in Los Angeles (~46 vol.%) is most similar to that in QUE94201 (46.0 vol.%; [7]) and greater than that in Shergotty (23.3%), Zagami (21.7%), EETA79001,A (17.1%) and EETA79001,B (29.1%) [8]. Although the high modal abundance of plagioclase may indicate that Los Angeles represents a cotectic liquid (i.e., non-cumulate), this appears inconsistent with the occurrence of large, blocky augite and pigeonite cores which may be "cumulus" crystals or xenocrysts.

A martian origin for Los Angeles is also indicated by the D/H ratio. Water enriched in D is characteristic of martian meteorites [9], especially apatite in shergottites [10,11], which have a D enrichment ranging from ~3-5 times terrestrial D/H values, probably representing the incorporation of D-enriched martian meteoric water into the minerals. This isotopic signature in apatite represents a unique fingerprint of martian samples in that it is present in all shergottite apatite grains previously analyzed and has not been reported in terrestrial or other meteorite samples. D/H values of two apatite grains in a thin section of stone 2 of Los Angeles were analyzed by ion microprobe at ASU using a 5-nA O_2^- primary beam, sufficient mass resolving power to separate D^+ from H^{2+} and a terrestrial amphibole standard. The two measurements yielded δD (SMOW) values of +3450 and +2630‰ with analytical uncertainties of ~±125‰. The accuracy of these data need further refinement with use of an apatite standard and possibly a slight background correction. However, previous analyses of standards and a background measurement on the analyzed thin section suggest the magnitude and direction of these corrections should approximately offset each other. It is clear that these apatite grains contain D-enriched water that is isotopically indistinguishable from comparable minerals in other shergottites, confirming the association of this new meteorite with the martian meteorite clan.

A further indication of martian origin is the rock's bulk composition [12] which shows characteristic ratios of Mn/Fe, Na/Al and Ga/Al.

References: [1] Greenwood J.P. et al. (2000) this volume; [2] Lindsley D.H. et al. (1972) *LS* **3**, 483-485; [3] Müller W.F. *GCA* **57**, 4311-4322; [4] Brearley A.J. (1991) *LPS* **22**, 135-136; [5] Milton D.J. and DeCarli P.S. (1963) *Science* **140**, 670-671; [6] Smith J.V. and Hervig R.L. (1979) *Meteoritics* **14**, 121-142; [7] McSween H.Y. et al. (1996) *GCA* **60**, 4563-4569; [8] McSween H.Y. (1985) *Rev. Geophys.* **23**, 391-416; [9] Leshin L.A. et al. (1996) *GCA* **60**, 2635-2650; [10] Watson L.L. et al. (1994) *Science* **265**, 86-90; [11] Leshin L.A. et al. (1996) *MPS* **31**, A79-A80; [12] Warren P.H. et al. (2000) this volume.