**LAP 02205, LAP 02224 and LAP 02226 - Lunar Mare Basaltic Meteorites. Part 1: Petrography and Mineral Chemistry.** K. H. Joy[1] (k.joy@ucl.ac.uk), I. A. Crawford[1], S. S. Russell[2], A. Kearsley[2]. [1] UCL/Birkbeck Research School of Earth Sciences, UCL, Gower Street, London, WC1E 6BT, [2]The Natural History Museum, Cromwell Road, London SW7 5BD, UK.

**Introduction:** The LAP lunar stones, collected during the 2002 and 2003 ANSMET field seasons in the LaPaz Ice Fields, Antarctica, represent the largest combined mass of lunar meteoritic material collected on Earth (~1875 kg). The meteorites LAP 02205 [1, 3, 4, 5, 6], 02224 and 02226 have been classified as lunar mare basalts [7]. We present a petrological and mineralogical investigation into the LAP stones – including the first detailed description of 02224 and 02226 and discussing possible launch pairing relationships. Allocated thin sections of LAP 02205(32), LAP 02224(35) and LAP 02226(25) and chips of LAP 02205(13) and LAP 02224(31) have been provided for this work from the Meteorite Working Group.

**Methods:** Mineral compositions were measured using a Cameca SX50A Wavelength Dispersive electron microprobe. Mineral maps (Fig. 1) were made using a JEOL 5900LV SEM and a LEO 1455VP SEM fitted with Oxford Instruments INCA energy dispersive X-ray microanalysers.

**Petrography:** The three stones are unbrecciated in nature and have a coarse-grained holocrystalline texture (Fig. 2) with phenocrysts up to ~1 mm in size. They contain apparently identical suites of typical lunar basalt minerals with similar subophitic to intergranular crystalline textural relationships.

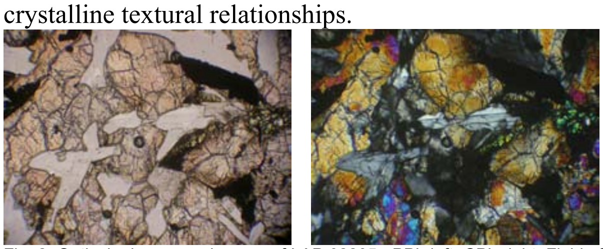

Fig. 2. Optical microscope images of LAP 02205. PPL left. CPL right. Field of view is 0.53mm by 0.4mm.

*Pyroxenes* in LAP 02205, 02224 and 02226 show comparable compositional variations (Fig. 3) from pigeonites and augites to extreme ferroan varieties. Mineral grains consistently display zonation from Mg-enriched cores to extremely Fe-rich rims (LAP 02205: $Fs_{21-90}$ $Wo_{9-41}$ $En_{0-58,}$ LAP 02224: $Fs_{23-86}$ $Wo_{8-39}$ $En_{1-59}$ and LAP 02226: $Fs_{22-87}$ $Wo_{8-40}$ $En_{0-55}$). The compositional trend is typically lunar [8], and originates from an evolving melt with an extreme late stage fractionation history. Based on pyroxene crystallisation alone, it is clear that the three meteorites originated from a geochemically similar basaltic parental melt. Many grains show evidence of shock pressures having

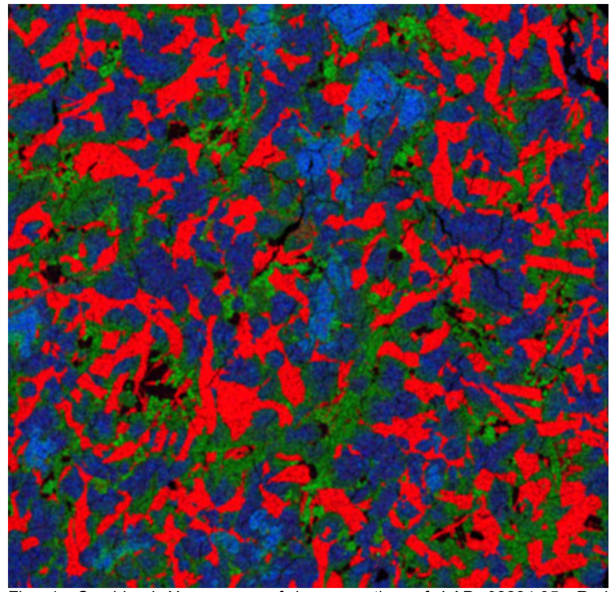

Fig. 1. Combined X-ray map of large section of LAP 02224,35. Red corresponds to Al-rich areas (plagioclase). Green represents Fe-rich areas (Fe oxides, pyroxene rims and the bright green areas pick out fayalitic olivines). Blue represents Mg-rich areas (pyroxenes and bright blue areas pick out forsteritic olivine phenocrysts. FOV is 5mm across.

undulatory extinction and internal shock deformation features.

*Plagioclases* within the stones have a very similar limited compositionally range (LAP 02205: $An_{91-81}$, LAP 02224: $An_{90-84}$, LAP 02205: $An_{90-84}$) (Fig. 3) and are poorly zoned. The plagioclase grains vary from being relatively pristine, with some still displaying twinning, to others having a glassy appearance caused by shock-induced vitrification. There is textural evidence of early skeletal crystallised plagioclases (dating from a pre-pyroxene crystallisation) and lath-shaped later varieties that were co-crystallised with pyroxene phases.

*Olivines* in the basalts fall into two groups. Large (200µm-1mm) zoned forsteritic varieties occur more frequently in 02224 (core values $Fo_{64}$–$Fo_{46}$) (Fig. 1) and 02226 ($Fo_{66}$–$Fo_{42}$) than in 02205 [1]. The LAP 02205 sample does contain a notably large olivine grain (Fig. 4a) with two small (<200µm) complex devitrified regions (Fig. 4b) (with a bulk chemistry of: 0.53% $Na_2O$, 3.02% MgO, 13.88% $Al_2O_3$, 54.39% $SiO_2$, 14.64% CaO, 4.48% $TiO_2$, 9.06% FeO) that may represent original trapped melt. Similar small devitrified patches have also been observed in olivines from 02226 and to a lesser extent 02224. Fayalitic olivines occur frequently in all of the stones (see Fig. 1 for distribution in 02224) as late stage melt products, intrinsically related to mesostasis areas, where they often form an anhedral groundmass. These fayalites may have formed as a result of the breakdown of unstable pyroxferroite at low pressure [9].

*Ilmenite* is common in the three stones and occurs as euhedral elongate crystals (50µm – 800µm) throughout the groundmass, and also as smaller subhedral masses in proximity to mesostasis areas. The relatively low abundance of ilmenite is evidence that this sample crystallized out of a low Ti-melt.

*Spinel* compositions in 02205, 02224 and 02226 show a limited crystallisation trend from more primitive Al-titanian chromites (which are often associated with forsteritic olivines) to late stage ulvöspinels.

Late-stage crystallisation products (mesostasis) form an important component of the LAP lunars. Irregularly shaped, these areas are formed of globules, usually <10 µm in size, of Si-K-rich glass enclosed by a fayalitic/pyroxferroite groundmass. They are heavily enriched in incompatible elements. Distinct silica grains (cristobalite) are frequent which suggests that the stones were crystallized from an evolved silica saturated melt. Accessory minerals include small blebs of troilite, FeNi metal grains and phosphate rich minerals.

**Observations and Sample Relationships:** even based solely on mineral chemistry and petrography there are notable similarities between the composition and texture of all the major components of LAP 02205, LAP 02224 and LAP 02226. The compositional ranges of spinels, pyroxenes, ilmenites, plagioclases and olivines (apart from Mg-depleted rims of forsteritic grains in 02224) is evidence that all of these stones were crystallized out of chemically related melt on the Moon.

The meteorites are also very similar in modal mineral counts [2] and in the presence of unusual and distinctive features such as the bleb-like mesostasis and the devitrified melt inclusions found in some olivine grains. We conclude that LAP 02205, LAP 02224 and LAP 02226 originate from a geochemically similar source, possibly even the same parent melt, that evolved to crystallize out highly fractionated minerals and mesostasis regions. They were probably launched by the same impact event, and broken up into separate stones either by this impact or on injection into the Earth's atmosphere.

Measurements of specific mineral trace element concentrations and relationships can be used to confirm this hypothesis. This work is in progress. Our accompanying abstract [2] discusses the geochemistry and specific features of the LAP paired lunar stones (02205, 02224 and 02226).

**References:** [1] Joy et al. (2004) LPSC *XXXV, Abstract #1545.* [2] Joy et al. (2005) LPSC *XXXVI* [3] Jolliff et al. (2004) LPSC *XXXV, Abstract* #1438 [4] Anand et al. (2004) LPSC *XXXV, Abstract* #1626 [5]Righter et al. (2004) LPSC *XXXV, Abstract #1667* [6] Mikouchi et al. (2004) LPSC *XXXV, Abstract #1548* [7] Antarctic Meteorite Newsletter. Vol. 27(1). [8] Heiken G. H. et al. (1991) The Lunar Sourcebook. *Cambridge Uni. Press* [9] Aramovich et al. (2001) LPSC XXXII, *Abstract* #1003.

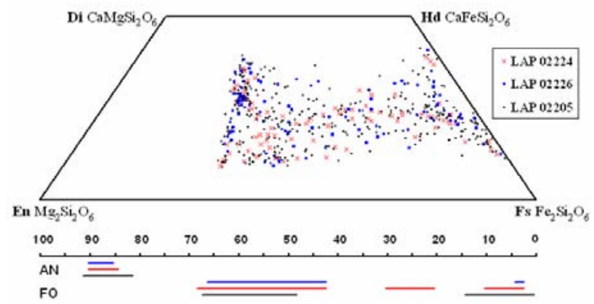


Fig. 3. Chemical composition of minerals in LAP 02205, LAP 02224 and LAP 02226. Pyroxenes are plotted onto a pyroxene quadrilateral. An number in plagioclases is shown by the upper set of lines and Fo in olivines by the lower set. In all cases LAP 02205 is black, 02224 is red and 02226 is blue.

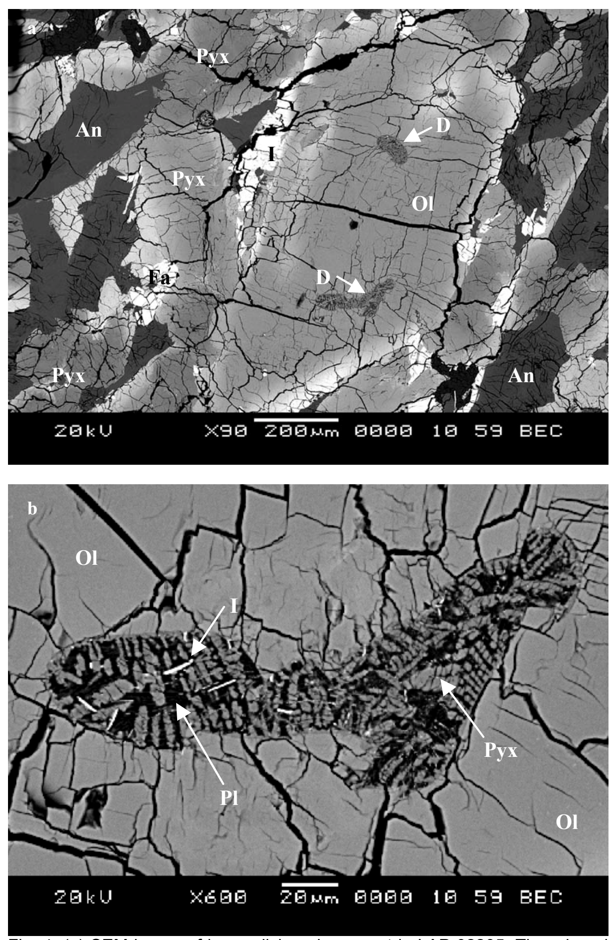


Fig. 4. (a) SEM image of large olivine phenocryst in LAP 02205. The mineral is zoned from $Fo_{63}$ core to $Fo_{39}$ rims and contains two small devitrified areas. (b) CU of lower devitrified area with microcrystalline texture. Ol=olivine, Pyx=pyroxene, An=Anorthite, D=devitrified area, I=ilmenite, Fa=fayalite, I=Ilmenite, Pl=plagioclase phase.