Mineral Chemistry of LaPaz Ice Field 02205 – A New Lunar Basalt. 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: LaPaz Ice Field 02205 (LAP 02205) is to date the heaviest lunar meteorite (1226.3g [1]) collected in the southern hemisphere, and is relatively free of terrestrial contamination, reflecting the relatively well-preserved nature of many Antarctic meteorites. Our thin section of the sample (~1cm by ~0.7cm) is unbrecciated in nature and has a coarse-grained crystalline appearance (with phenocrysts up to ~1mm in size). The meteorite exhibits a sub-ophitic texture with elongate pyroxene crystals (53%) partially surrounding euhedral lath-shaped plagioclases (38%), rare olivines (trace), anhedral silica (2.2%), interstitial oxides (4.7%) (ilmenite and spinels), sulphides and trace metal FeNi. There is a significant amount (4.3%) of mesostasis which is dominated by incompatible element enriched glasses and sulphides. Point counting modal analysis of the section of LAP 02205 in combination with mineralogical observations it is compatible with a lunar mare basalt (Fig.1) [2]. The bulk composition (Table 1) Lap 02205 is quite similar to Luna 16 Al-rich basalt samples but with a higher Fe content.

Lunar Origin: Oxygen isotope analysis, carried out in the preliminary petrography description [1] of LAP 02205, gives $\delta^{18}O$ of +5.6 ‰ and $\delta^{17}O$ of +2.7‰ which is consistent with a lunar origin. An analysis of the Fe/Mn atomic ratio of pyroxenes within the sample affirms this, as they are clustered on the average Moon Fe/Mn line (Fig. 2 [3] [4]).

Mineralogy and whole-rock composition: Mineral compositions were measured using a Cameca SX50A Wavelength Dispersive electron microprobe. Pyroxene compositions show substantial variation in chemistry throughout the meteorite (Fig. 3) from orthopyroxenes to pigeonites and augites. They consistently display zonation from slightly magnesium-enriched pigeonite cores to extremely Fe-rich rims (Fs_{36-94} Wo_{8-40}). This zonation could represent a relatively slow cooling. The trend in pyroxene composition is indicative of a late stage fractionation trend – there is a complete lack of early stage enstatitic forms. Additionally, some pyroxenes display exsolution lamellae of <1µm, again suggesting that LAP 02205 underwent slow cooling.

Plagioclases within the meteorite are relatively pristine with some still displaying twinning and a small amount exhibiting minor levels of shock-induced maskelynisation. Typically lath-shaped, plagioclases are euhedral to subhedral in form suggesting a relatively slow cooling rate (there is no evidence of rapid quenching). Chemically there is quite a broad range of compositions (Fig. 4) with occasional Ca-content as low as An_{68}, but with the majority around An_{90} (bytownite / anorthite), which fits well with the range of compositions detected within Apollo basalts [2]. There are instances where plagioclase phenocrysts partially enclose pyroxenes suggesting that they co-crystallised. In plagioclases that are adjacent to mesostasis areas there is often a slight elevation in the level of K enrichment, illustrating that the sample contains a residual melt stage.

Our section of LAP 02205 only contained trace levels of olivine, and indeed was only found in xenocryst form (inherited from an earlier stage of melt evolution), as relict core areas of pyroxenes with Fo_{55} – Fo_{56}. This lack of olivine is significant in that it suggests an evolving magma composition with olivine undergoing reactions to form pyroxene as the rock became silica saturated.

Ilmenite is the most common oxide occurring as euhedral elongate crystals (50µm – 800µm) throughout the sample, often showing alignment with the surrounding pyroxene and plagioclase phenocrysts. The relatively low abundance of ilmenite suggests that this sample crystallized out of a low Ti melt. Rare spinels show a range of chemistries from ulvöspinel to Al-titanian chromite. There is also quite a high silica mineral abundance for a lunar basalt (2.2%, probably cristobalite, showing conchoidal fracturing as a result of inversion from high-temperature to low-temperature structure, Fig.1), which again suggests that this rock was derived from an evolving magma source.

In a similar manner to lunar basalt meteorite Dhofar 287a [5] [6], areas of mesostasis form an important component of LAP 02205. These irregularly shaped areas are formed of globules, usually <10µm in size, of silica, fayalites, pyroxferroite and glasses enriched in incompatible elements like K, Ba and Cr. Small (<100µm) accessory sulphide minerals occur throughout the meteorite, usually associated with the mesostasis and in the form of troilite. There are rare FeNi grains also affiliated with these late stage crystallization regions.

Our provisional bulk composition for LAP 02205 was obtained by making broad beam compositional measurements (approximately 1.0 x 0.7 mm in area) from four representative areas of the sample. This was achieved using a JEOL 5900LV SEM fitted with an

Oxford Instruments INCA energy dispersive X-ray microanalyser, with 20kV accelerating voltage and 2nA beam current. The average values are listed in Table 1, together with their standard deviations. The reliability of this technique was tested by taking a grid of 25 regularly spot measurements within each area, the averages of which all agree with the values given in Table 1 (with the single exception of FeO, where this technique yielded a value 1.3 standard deviations higher than the broad beam value). The broad area analyses are therefore considered representative.

Discussion: As the total collection of known lunar basalts is very limited it is likely that this sample represents an unsampled lithology that has similar characteristics, but no exact match to any rocks for which a description exists. On the basis of the bulk composition we infer that the meteorite is similar to the low-titanium feldspathic basalts retrieved from the Luna 16 mission to Mare Crisium and could be termed 'slightly KREEPy' due to the abundance of K enriched mesostasis regions. In terms of pyroxene content and Fe abundance it is also similar to Apollo 12 pigeonite basalts [4]. Thus, being a basalt with a relatively high Fe content, it is very likely that it was originally emplaced on the lunar near-side in a mare region. This meteorite probably represents a relatively slowly-cooled residual melt with a slightly more evolved mineralogy than most mare basalts.

Table 1. Bulk Composition

Element	Composition (comp. %)
Na_2O	0.36±0.22
MgO	6.04±2.39
Al_2O_3	12.20±1.35
SiO_2	45.06±0.52
K_2O	0.14±0.14
CaO	10.63±0.86
TiO_2	3.86±0.98
MnO	0.10±0.18
FeO	21.23±1.34
Cr_2O_3	0.1± 1.34
Total	99.99

References: [1] McCoy T. et al (2003) *Antarctic Meteorite Newsletter, Vol. 26 No 2.* [2] Heiken G. H. et al. (1991) *The Lunar Sourcebook.* Cambridge Uni. Press. [3] Anand M. (2003) *Geochim. Cosmochim.* Acta 67, 3499-3518 [4] Papike J. J. (1998*) Planetary Materials*. pp 7.1 -7.11. [5] Anand M. (2002) *LPS XXXII,* Abstract #1635 [6] Anand M. (2003) *LPS XXXIV,* Abstract #1787.

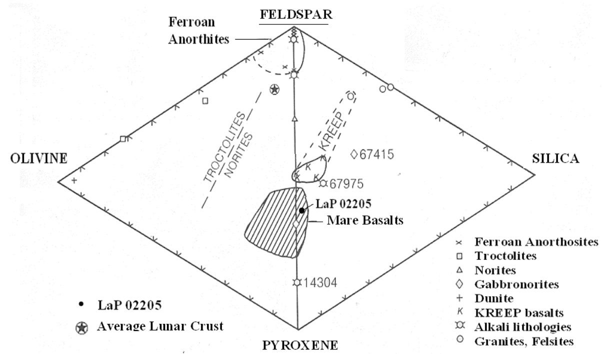

Fig. 1: Classification of LAP 02205 from modal mineralogy

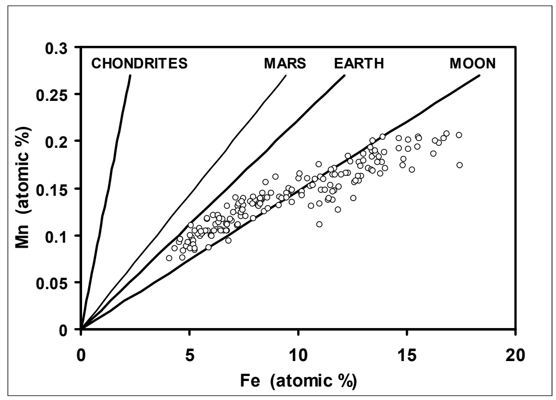

Fig. 2: Verification that LAP 02205 originated from the Moon – Pyroxene Fe/Mn ratio plot showing scatter

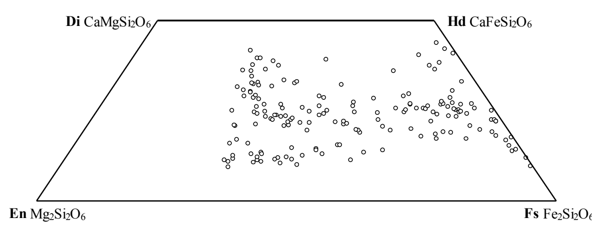

Fig. 3: Plot of pyroxene compositions in LAP 02205

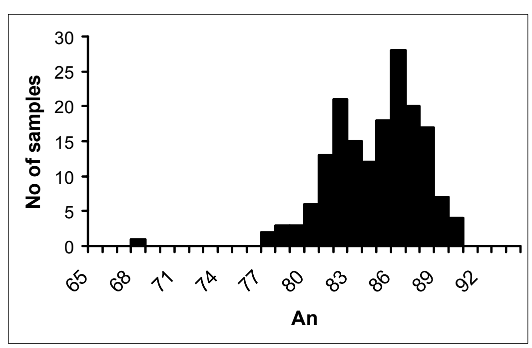

Fig. 4: Plot of plagioclase composition range in LAP 02205